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The Explorers Guide to the ZX81

Mike Lord

Timedata

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Programming Aids.

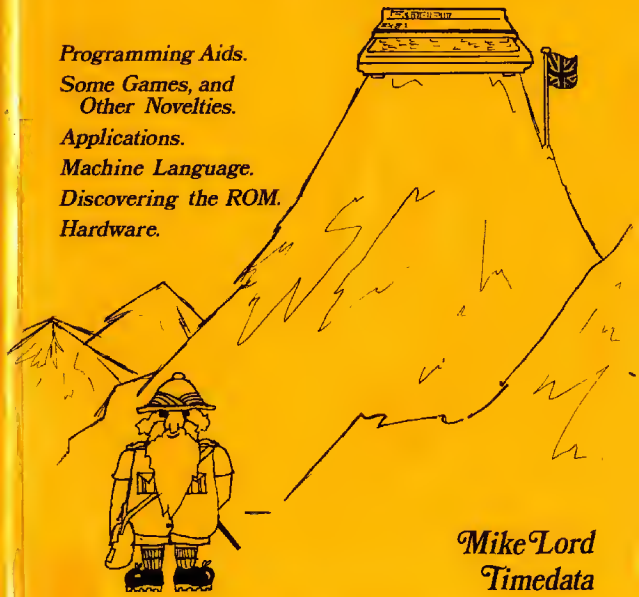
Some Games, and Other Novelties.

Applications.

Machine Language.

Discovering the ROM.

Hardware.



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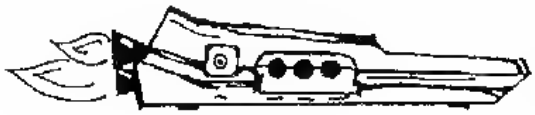

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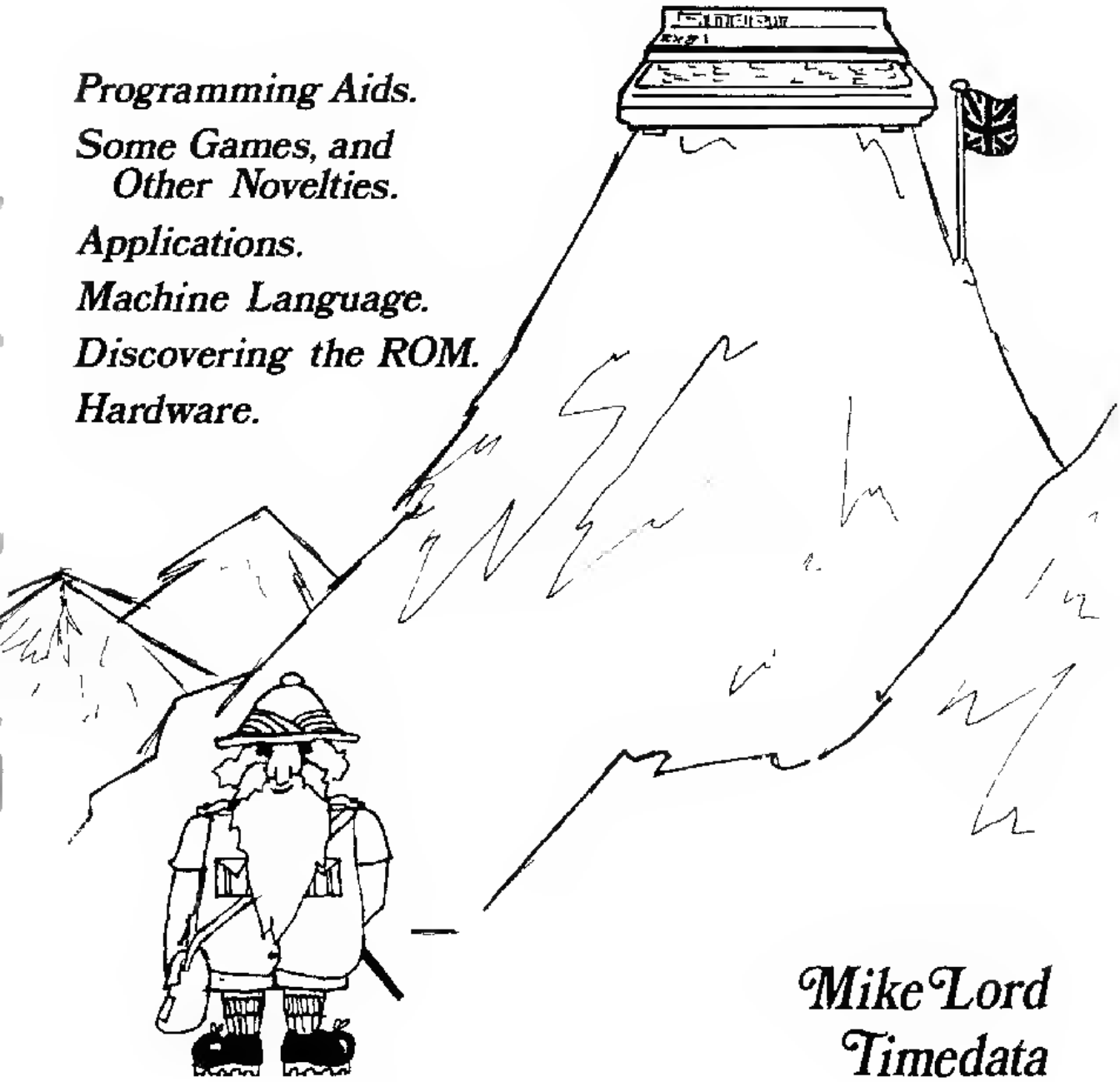

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The Explorers Guide to the ZX81

Written by Mike Lord, including material by John Durst and S.J.Newett. Drawings by Sonia Lord.

This book is dedicated to Clive Sinclair for making it all possible.

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The Explorers Guide to the ZX81

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INTRODUCTION

Welcome, fellow explorer, to the world of the ZX81.

First, a few words about the contents of this book. It is not intended to be a beginner's guide to BASIC, or even an introduction to the ZX81, as many excellent books on these subjects already exist.

Instead, this guide attempts to carry the reader on from where the ZX81 BASIC Manual leaves off, by giving a variety of programs to run, and - more importantly - a wealth of detailed information about this computer and how to get the best out of it.

Whether your interests lie in games programs, in the business or engineering uses of the ZX81, or even in attacking it with a soldering iron, you should find something of interest in these pages.

But I hope that the most valuable thing the reader will find in this book is the impetus to carry on investigating, to write his own programs, and to pursue his own explorations into the mysteries of this marvelous machine.

Mike Lord

Some notes about the program listings in this book;

- Programs are intended to be run in the Slow mode unless otherwise stated.
- Programs which will fit into 1K RAM are so marked. Other programs were written for 16K but in practice most will fit into a ZX81 with only 4K of RAM.
- The number zero is written as 'Ø' throughout the program listings to distinguish it from the letter O.
- Only two programs (Ladder Analysis and Bank) use multiple character variable names. In all of the other programs, any time you see 2 or more letters together then that is a *keyword*, to be entered by a single keystroke.
- To avoid confusion the 'double character' keywords ** and "" have not been used. Neither have the inverse (white on black) letters been included in any of the programs - although you are free to incorporate them where you feel it will liven up the display.
- The '<=','>=' and '<>' keywords have, however, been used. Remember that these are entered by a single keystroke.
- Graphics characters have been drawn as they appear, thus '▟' represents the graphics character on key Q.

The later ZX81's have the legend 'ENTER' instead of 'NEWLINE' on the rightmost key, and 'DELETE' rather than 'RUBOUT' on the top right key. Please make any mental corrections necessary as you read if you have one of these models, and forgive us for not showing both versions throughout the book !

Chapter 1

Programming Aids

THE PROGRAMMER'S SONG OF TRIUMPH

The first version I wrote was the first that I sold.
The second one worked. But then I was bold
And re-wrote it again. And again. And again.
Each issue was better by far than the last.
And now its so short, and so neat, and so fast,
You can't buy it for dollars, but only for Yen.

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Saving Space

The major limitation of the basic ZX81 is the amount of RAM available. Of the 1K (1024) bytes, 125 bytes are used for the ZX81's System Variables, between 25 and 793 bytes are used for the Display File, and a variable amount is taken up by the Calculator, Machine and Gosub stacks. You can end up with very little space left for your program and its variables.

Display Small

As the Display File can be very greedy for RAM, we should look first at how its appetite can be curbed. If you have 4K bytes or more, then there is nothing you can do; as the Display File is then always kept in its fully expanded 793 byte form.If, however, you have less than 4K bytes of RAM, then read on ;

The judicious use of CLS statements can help by collapsing the Display File to the minimum 25 bytes. Having done this, then concentrate your efforts on keeping the Display File as small as possible. PRINT and PLOT as little as possible, and when you do then do it on the left hand side of the screen rather than in the middle or on the right. This is because whenever anything is displayed on the right hand side of the screen, the Display File has to hold all of the spaces leading up to it, whereas the ZX81's clever design doesn't need the Display File to hold trailing spaces in a line. Note also that if you delete anything from the display by over-printing it with spaces, then the spaces remain in the Display File - taking up valuable RAM - even though the resulting line may be totally blank.

Think Small

Having cut the Display File down to size, it is time to look at the program itself. Obviously the algorithm chosen will have a major effect on the length of the program, as will the number of 'frills' you include - such as checking inputs for validity, formatting outputs, and providing user prompts - and it is impossible to give any guidelines for these factors except perhaps to say that re-thinking your ideas will usually prove fruitful. Remember the Old Programmer's saying;

"He who thinks most bytes least"

It is usually possible to save several bytes by taking a detailed look at each line of the program and - with the aid of the table at the end of this section - seeing if alternative renderings would occupy less space. Some things to look for are given in the following paragraphs.

Small Tricks

Numeric constants - such as 'Ø' or '99.99' use one byte for each character *plus six bytes to hold the binary equivalent of the number*. Thus the line;

```
10 IF A>55 THEN LET A=55
```

uses 28 bytes, whereas

```
10 LET Z=55
11 IF A>Z THEN LET A=Z
```

takes a total of 30 bytes for both lines, plus 6 bytes in the Variable Area to hold the new variable Z. This appears to be a backward step, but if the constant 55 were used in other places in the program, and if the variable Z could perhaps be re-used, then an overall saving could be made.

Alternatively, we can often use the function CODE to generate a numeric constant - although at the cost of making the program more difficult to understand. Noting that CODE "R" equals 55 and occupies only 4 bytes of program space, the example given above could be written as;

```
10 IF A>CODE "R" THEN LET A=CODE "R"
```

and this version would take only 20 bytes, a saving of 8 bytes over the original.

The VAL function is also useful, as for example

```
10 LET A=VAL "356"
```

uses 3 less bytes (but takes longer to execute) than;

```
10 LET A=356
```

If you want the numbers '0' or '1', then short equivalents are NOT PI and PI/PI, saving 5 & 4 bytes respectively.

Variables should be re-used wherever possible, especially FOR loop control variables, to hold down the size of the Variable Area of RAM.

Multi-character variable names may give a clue to how the program works, but they use up RAM. Use only single character names wherever possible. Similarly, explanatory REM statements are better hand-written on your copy of the program listing.

One long PRINT statement can often take less memory than two short ones.

Make the program finish at the last line, to remove the need for a STOP statement.

AND is often a slightly shorter alternative to IF - - THEN. For example;

```
10 IF A>B THEN PRINT "BIG"
```

takes 16 bytes, whereas;

```
10 PRINT "BIG" AND A>B
```

takes 15.

Using parentheses in arithmetic and string expressions uses RAM not only for the '(' and ')' symbols but also as a temporary store for the intermediate result when the program is run. Similarly, GOSUBs use extra RAM when the program is run - to hold the return addresses.

If an expression is used several times within a program, it may be possible to save space by defining a string as that expression and then using VAL to execute it as required.

If numeric or string variables have to be set to fixed values at the start of your program, then a potent way of saving space is by assigning their values by direct commands - even to the extent of DIMensioning any arrays directly. But remember that you can't RUN such a program, but must start it with GOTO to preserve the assigned values. To see how this works, enter the program;

```
10 SAVE "TEST"
20 PRINT A,B,C(1),C(2)
30 PRINT "AGAIN ?"
40 INPUT D$
50 IF D$="Y" THEN GOTO 20
```

Then enter the following lines as direct commands (i.e. without line numbers);

```
CLEAR
DIM C(2)
LET A=1
LET B=2
LET C(1)=3
LET C(2)=4
```

Then GOTO 20 should display the stored values, and GOTO 10 will save the program and the values on tape so that if it is subsequently LOADed, the values will be recovered and then printed out. This technique should - however - be used with caution as it becomes very difficult to debug a program containing 'invisible' data.

Taking slices of a fixed string is often an economical way of dealing with a list of fixed data (characters, strings or numbers), and is less error-prone than using the 'invisible data' technique. For example;

```
10 DIM A(4)
20 DIM B$(4)
30 DIM C$(4,3)

50 FOR I=1 TO 4
60 LET A(I)=VAL "1248"(I)
```

```
70 LET B$(I)="ZX81"(I)
80 LET C$(I)="ROMRAMZ80IBM"(3*I-2 TO 3*I)
90 NEXT I
```

will load the elements of the array A() with the numbers 1,2,4,8 the elements of the character array B$() with the characters Z,X,8 and 1 , and the string array C$() with the words ROM RAM Z80 and IBM. See the programs "Roman - Arabic" and "Arabic - Roman" for other examples.

Shrunken Arrays

It takes 5 bytes to hold each value in a numeric array, but if you only want to store a limited range of values, then you can save space by storing the values in a character array, using the CODE and CHR$ functions. For example, to input and store 20 values each in the range 0 to 255;

```
10 DIM A$(50)
20 FOR B=1 TO 20
30 INPUT X
40 LET A$(B)=CHR$ X
50 NEXT B
```

and to print them out;

```
100 FOR B=1 TO 20
110 PRINT CODE A$(B)
120 NEXT B
```

A larger range of values can be accommodated by taking two or three bytes of a character array to hold each value.

How Much

If you want to find out how much RAM has been used, remember that;

```
PRINT PEEK 16396 + 256*PEEK 16397
```

gives the address of the beginning of the Display File, which follows immediately after the end of the Program Area.

```
PRINT PEEK 16400 + 256*PEEK 16401
```

gives the address of the start of the Variable Area, which follows immediately after the end of the Display File.

```
PRINT PEEK 16404 + 256*PEEK 16405
```

gives the address of the first free byte after the end of the variables area.

But also remember that the RAM above the end of the Variables area cannot be considered completely free, as the ZX81 uses this area for various stacks and you may (by re-assigning RAMTOP) have reserved some for USR routines.

If you want to investigate the way that programs,data and the display file are held in RAM, the "Peeker" programs given elsewhere in this book will be useful.

RAM Space

RAM SPACE USED BY VARIOUS ZX81 BASIC ELEMENTS

The number of bytes needed to store a program line is not the same as the number of characters shown when the line is LISTed, but may be calculated from the figures given below.

	Bytes used in program area
Any number except a line number at the start of a line.	6 plus one for each character in the LISTed number.
Any keyword, function, statement or operator.	1
Any other graphics or alphanumeric character appearing in the LISTed form of the line.	1

In addition, each program line takes 2 bytes to store the line number (in binary form), 2 bytes to store the length of the stored line, and one byte for the NEWLINE code at the end of the line.

As an example, the line;

```
                10 LET A(I) = 8
takes;             1   4   1 7      plus 5 = 18 bytes
```

Each variable used also takes up space in the Variables Area of RAM;

	Bytes taken in variable area
FOR control variable.	18
Other numeric variable.	5 plus one byte for each character in the variable's name.
Numeric array.	4 plus 2 bytes per dimension plus 5 bytes per element.
String variable.	3 plus 1 byte per character in the string.
Character array.	4 plus 2 bytes per dimension plus 1 byte per element.

Other Hints

Fixed Headings

For reasons not revealed to the author, the CLS command counts 24 NEWLINEs backwards from the end of the display to find the beginning. This means that if we POKE an extra NEWLINE code into the Display File, then CLS will not affect the first line. As a demonstration, run;

```
 1Ø PRINT "TITLE LINE*"
 2Ø POKE (11+PEEK 16396+256*PEEK 16397),118
 3Ø FOR A=1 TO 3
 4Ø FOR B=1 TO 21
 5Ø PRINT AT B,Ø;B
 6Ø NEXT B
 7Ø PAUSE 5Ø
 8Ø CLS
 9Ø NEXT A
1ØØ POKE (11+PEEK 16396+256*PEEK 16397),Ø
11Ø CLS
```

The NEWLINE code (118) is POKEd in place of the '*' in the title line by line 20, and later removed by line 100.

Note that this program actually prints on the 23rd. display line.

RAMTOP Check

If you have a program which needs the System Variable RAMTOP to be changed before LOADing, it is perhaps worth including a check that this has been done at the start of the program,e.g;

```
 1Ø IF PEEK 16388+256*PEEK 163B9=174Ø4 THEN GOTO 2Ø
 11 PRINT "RAMTOP WRONG"
 12 STOP
 2Ø - - - -
```

(The correct value for RAMTOP is assumed to be 17404)

Spacey Strings

A string consisting of a defined number of spaces is often useful, and the easiest way to generate it is by using a DIM statement. For example;

```
DIM A$(32)
```

creates a string A$ of 32 spaces.

DIM Strings

If you are using a string array, then remember that the length of each string in the array is always fixed (by the DIM statement). Thus;

```
10 DIM A$(2,5)
20 LET B$="ABC"
30 LET A$(1)=B$
40 PRINT A$(1),LEN A$(1),B$,LEN B$
```

will print out

```
ABC                 5
ABC                 3
```

showing that A$(1) always retains the length of 5 characters.

When a string element of a string array is assigned a new value, then the new value is either truncated or packed out at the end to bring it to the correct length.

This can be awkward when trying to search through a string array for - say - a matching name, as the comparison will have to take account of any 'spare' spaces. For example, the program;

```
10 DIM A$(2,5)
20 LET A$(1)="ME"
30 IF A$(1)="ME" THEN PRINT "FOUND ME"
```

won't actually print anything, as the two strings being compared in line 30 are of different lengths.

One solution to the problem lies in dimensioning a test string to have the same length as the strings in your array, and then using that test string in the comparison;

```
10 DIM A$(2,5)
20 DIM X$(5)
30 LET A$(1)="ME"
40 LET X$="ME"
50 IF A$(1)=X$ THEN PRINT "FOUND ME"
```

will work as expected.

CLEAR before SAVE

If you don't need to save the values of the variables with your program, then a CLEAR command before the SAVE reduces the amount of information the ZX81 has to put onto the tape. This cuts down the time taken to SAVE, and later to LOAD, the program, and so reduces the chance of an error.

VAL Functions

If an expression is repeated several times within a program, then it may be worth defining it as a string, then using VAL to execute it when required. For example, suppose the line

```
LET Z=SQR (X*X+Y*Y)
```

was used several times, then we could insert a line at the start of the program;

```
LET Z$="SQR (X*X+Y*Y)"
```

then subsequently write;

```
LET Z=VAL Z$
```

Pretty Printing

To print A$ centrally on a line, use;

```
        PRINT TAB 16-LEN A$/2;A$
or      PRINT AT n,16-LEN A$/2;A$
```

To right-justify A$, use;

```
        PRINT TAB 32-LEN A$;A$
or      PRINT AT n,32-LEN A$;A$
```

Printing a column of numbers so that they line up properly is easy if they are all integers, as illustrated by the following;

```
10 LET A=0
20 FOR B=1 TO 9
30 LET A$=STR$ A
40 PRINT TAB 12-LEN A$;A$
50 LET A=10*A+B
60 NEXT B
```

```
       0
       1
      12
     123
    1234
   12345
  123456
 1234567
12345678
```

But if decimal fractions are involved, a special routine is needed to line up the decimal points, as lines 30-70 of the demonstration program below;

```
10 LET A=PI*.00001
20 FOR B=1 TO 18
30 LET A$=STR$ A
40 FOR C=1 TO LEN A$
50 IF A$(C)="." THEN GOTO 70
60 NEXT C
70 PRINT TAB 14-C;A$
80 LET A=A*10
90 NEXT B
```

```
.000031415927
.00031415927
.0031415927
.031415927
0.31415927
3.1415927
31.415927
314.15927
3141.5927
31415.927
314159.27
3141592.7
31415927
314159270
3141592700
31415927000
314159270000
3141592700000
```

We often want to round results off to a maximum number of digits after the decimal point. The INT function can be used to do this as for example in the following routine which rounds to 3 decimal places after the point;

```
10 LET A=PI/10000
20 FOR B=1 TO 10
30 PRINT INT (.5+A*1000)/1000
40 LET A=A*10
50 NEXT B
```

```
0
.003
.031
0.314
3.142
31.416
314.159
3141.593
31415.927
314159.27
```

The decimal points could be lined up if required using the technique given earlier. However, this form of output is not ideal for monetary values such as pounds and pence, or dollars and cents; it would show for example one dollar and thirty cents as '1.3', which although mathematically correct, is not what the customer is used to.

To print in a more acceptable format, a routine such as that included in the demonstration program below is needed. This example also lines up the decimal points;

```
10 LET A=PI/1000
20 FOR B=1 TO 10
30 LET A$=STR$ INT (.5+A*100)
40 IF LEN A$=1 THEN LET A$=A$+"0"
50 IF LEN A$=2 THEN LET A$="0"+A$
60 PRINT TAB 10-LEN A$;A$( TO LEN A$-2);".";A$(LEN A$-1 TO )
70 LET A=A*10
80 NEXT B
```

```
   0.00
   0.30
   0.31
   3.14
  31.42
 314.16
3141.59
31415.93
314159.27
3141592.70
```

Other BASICs

A wealth of programs written in 'BASIC' can be found in other books and in computer magazines. But sadly there are many versions of 'BASIC'. Although they may look similar, there are enough differences between the versions that a program written for another machine probably won't work on the ZX81 without some changes.

To help you find out what changes are needed, the following paragraphs list the main differences between ZX81 BASIC and the dialects used by other popular machines. But note that the extent and nature of the changes needed will depend on the structure of the program being converted, on how it handles data, and - most importantly - on the screen display characteristics of the particular machine it was intended to run on. So work out exactly how the program works before attempting to run it on the ZX81, it will save time in the long run.

Multiple-statement lines

Some BASICs allow multiple statements on a line, usually separated by ':' or '\' (the Acorn Atom uses ';') e.g;

```
10 LET A=B+C : LET D=2*D+A : PRINT A,D
```

These will have to be written on separate lines for the ZX81;

```
10 LET A=B+C
11 LET D=2*D+A
12 PRINT A,D
```

Variables

Most modern BASICs use floating point arithmetic and variables like the ZX81, but some also allow you to specify *integer* variables by adding a '%' to the variable name. Thus;

A would be a floating point variable.
A% would be an integer variable.

An integer variable is one which can only have integer (whole number) values. They are usually used because they take up less memory space than floating point variables, or because arithmetic using integer variables is usually faster, and in these cases there is no real harm in using the ZX81's floating point variables instead. But, occasionally, the program may rely on the properties of integer arithmetic, particularly integer division where the result is rounded down to give an integer result. If you suspect that this might be the case, then use the ZX81 INT function to 'integerise' the result of any division. E.g;

```
10 LET C%=Y%/100
```

would become;

```
10 LET C=INT (Y/100)
```

A few BASICs, such as Apple II Integer BASIC, and 4K ZX80 BASIC, don't have floating point variables; all their variables are integer types even though they don't have the '%' symbol at the end of each variable name. Atom BASIC is even more confusing, as variables of the form 'A' are *integer* variables, while *floating point* variable names begin with '%', e.g. %A. Again, be wary of divisions.

Arrays

There should be no difficulty with numeric arrays, as the ZX81's capabilities are at least the equal of other machines. Note, however, that in most other BASICs subscripts start at zero, not at one. Thus DIM A(3) usually defines a four element array A(0) to A(3), whereas the ZX81 would create a three element array A(1) to A(3).

Some BASICs allow the use of multi-character variable names for arrays, these will have to be changed to single letter names for the ZX81.

The ZX81's string array facilities are also similar to those of most other machines (except that - again - most other BASICs start their subscripts at 0 rather than at 1). But there are differences in how they deal with the length of strings in an array. The DIM statement in most BASICs defines - as well as the size of the array - the *maximum* length of each string. Strings assigned to the array keep their original length unless they are too long, when an error report occurs. This is different to the ZX81's practice of adjusting the size of a string to make it fit exactly the string length DIMensioned for that array. The only real problem this might give is when comparing string variables, as discussed in 'DIM Strings' elsewhere in this book.

The following form of string array DIM statement may often be found;

```
DIM A$(2,2)[10]
```

This defines a 2x2 (or 3x3) string array, each element having a maximum length of 10 characters. It is equivalent to the ZX81's

```
     DIM A$(2,2,10)
or   DIM A$(3,3,10)
```

Some BASICs require that every string variable - even those that are not array variables - be DIMensioned to reserve memory space for it. Other BASICs only require DIM statements for string variables which are likely to be longer than - say - 10 characters. In either case, you will encounter program lines such as;

```
DIM B$(10)     or     DIM C$[10]
```

which are not needed in the ZX81 version of the program.

Some BASICs allow more than one array to be DIMensioned by a single DIM statement, this cannot be done on the ZX81. Thus;

```
10 DIM A(2,2),B(50)
```

would have to be written as;

```
10 DIM A(2,2)
11 DIM B(50)
```

Arithmetic functions

Those used by the ZX81 are very similar to those available on other computers, except that some BASICs use the symbols '^' or '↑' instead of the ZX81's '**'.

Also, on some computers LOG is equivalent to the ZX81's LN, while others have both LN (logarithm to the base e ; as the ZX81's LN) and LOG (logarithm to the base 10).

ASC , CHR$

ASC(X$) returns the decimal value of the code for the first character in X$ and is therefore similar to the ZX81's CODE X$. Note, however, that most computers use the international standard ASCII code to represent characters, but the ZX81 is an exception. Thus ASC("A") gives a value of 65 on most machines, but CODE "A" on the ZX81 gives 38.

Apart from this coding difference, the ZX81's CHR$(X) function behaves the same as in other BASICs.

DATA , READ , RESTORE

These statements are included in many BASICs to allow a list of fixed values to be handled easily. DATA statements in a program establish the list, e.g;

```
100 DATA 7,2,5
110 DATA 12,13
```

then each READ statement takes the next value from the list, so;

```
200 FOR I=1 TO 5
210 READ A(I)
220 NEXT I
```

would load the values 7,2,5,12,13 into the array elements A(1) to A(5). RESTORE re-sets an internal 'pointer' to the start of the DATA list so that the next READ statement will get the first DATA item.

The most obvious way of simulating these statements in a ZX81 program is by a sequence of LET statements, e.g;

```
200 LET A(1)=7
201 LET A(2)=2
          etc.
```

Or - to save memory - you could store the values in the array by using direct LET commands (i.e. by entering the LET lines without line numbers). But don't forget that the associated DIM statements must have already been executed to set up the arrays, and when you have finished entering the values use GOTO rather than RUN to re-start the program or you'll lose all those

laboriously entered values.

Using sliced strings is sometimes a better way of handling a lot of fixed data, as discussed in 'Saving Space'.

DEF FN

A statement of the form

```
10 DEF FNA(X)=X+X*X
```

is acceptable to most BASICs, and is taken to define a new function FNA(X) which will give the value X+X*X and can be used with different parameters during a program. Thus;

```
20 LET A=3*FNA(2)
30 LET B=FNA(A/2)
```

would give A the value 18, and B the value 90.

Usually up to 26 different functions - FNA() to FNZ() - can be defined.

One of the most annoying features of ZX81 BASIC is that it does not allow functions to be defined in this way.

We can write out the function in full each time it is encountered;

```
20 LET A=3*(2+2*2)
30 LET B=A/2+A*A/4
```

Or we could use a subroutine, but we will have to assign the correct value to each variable used by the subroutine before it is called, and re-assign the result on return;

```
20 LET Z=2
21 GOSUB 100
22 LET A=Z
30 LET Z=A/2
31 GOSUB 100
32 LET B=Z
---------
100 LET Z=Z+Z*Z
101 RETURN
```

Alternatively, we could define a string variable as the required function, then execute it by a VAL function when required. But again we have to assign the correct value to each variable used in the function before it is used;

```
10 LET Z$="Z+Z*Z"
--------
20 LET Z=2
21 LET A=VAL Z$
30 LET Z=A/2
31 LET B=VAL Z$
```

END

Replace by STOP.

FOR · · TO · · STEP

Some BASICs allow FOR variables to have multi-character names. These will have to be changed to single character names for the ZX81.

GET

Available in some BASICs, a statement of the form;

```
10 GET A$
```

waits for the user to press a key, then returns a single character string as A$.
INKEY$ is similar, but is a function rather than a statement, and does not wait for a key to be pressed. The ZX81 equivalent to the above line would be;

```
10 LET A$=INKEY$
11 IF A$="" THEN GOTO 10
```

GOTO, GOSUB

Some BASICs do not allow a 'computed' GOTO or GOSUB, such as the ZX81's GOTO A+100 . You may therefore be able to simplify a program slightly by taking advantage of this facility.

A few BASICs let you include a 'label' at the beginning of a line, immediately before or after the line number. This 'label' usually looks like a variable name, and may be followed by a semi-colon. The label can then be used after a GOTO or GOSUB instead of the target line number, e.g;

```
10 GOTO A
-------
100 A LET C=D
```

Which translates to;

```
10 GOTO 100
-------
100 LET C=D
```

Some BASICs have 'ON - - GOTO' and 'ON - - GOSUB' forms. These make the program GOTO (or GOSUB) one of a number of lines, depending on the value of a variable. For example;

```
10 ON I GOTO 100,105,130
```

will jump to line 100 if I=1, to 105 if I=2 or to 130 if I=3.

Depending on the particular example, these forms may be replaced by a computed GOTO (or GOSUB) or by a sequence of IF - THEN - GOTO lines.

Or, you can be really tricky and use the AND operator, so the ZX81 version of this line would be;

```
10 GOTO (100 AND I=1)+(105 AND I=2)+(130 AND I=3)
```

IF··THEN

Most BASICs will allow you to write

```
IF - - THEN 100
```

instead of;

```
IF - - THEN GOTO 100
```

Some BASICs won't allow anything except a line number after the THEN. Programs written in these dialects may sometimes be simplified by taking advantage of the ZX81's ability to execute any statement following a THEN. Thus;

```
10 IF X>10 THEN GOTO 30
20 PRINT "TOO LOW"
30 ----
```

could be re-written as;

```
10 IF X<=10 THEN PRINT "TOO LOW"
30 ----
```

BASICs that allow multiple statements in one line usually also let you put multiple statements after a THEN, such as;

```
10 IF A>B THEN PRINT "A>B";LET A=B;GOTO 30
20 PRINT "A<=B"
30 ----
```

which would have to be re-written along the lines of;

```
10 IF A<=B THEN GOTO 20
11 PRINT "A>B"
12 LET A=B
13 GOTO 30
20 PRINT "A<=B"
30 ----
```

Note that BASICs differ in their interpretation of a *value* as being 'true' or 'false'. Thus;

```
10 IF A THEN PRINT "TRUE"
```

will print TRUE on a ZX81 if A is non-zero, whereas other versions of BASIC may recognise - for example - negative values as the Boolean 'false', and zero values as 'true'.

INPUT

Some forms of BASIC allow a 'prompt' string to be included in an INPUT statement. This string is printed out before the INPUT is performed, thus;

```
10 INPUT "NAME",N$
```

which would have to be re-written as;

```
10 PRINT "NAME"
11 INPUT N$
```

Also, some BASICs allow a single INPUT statement to get more than one value, e.g;

```
10 INPUT M,N
```

which becomes, for the ZX81 ;

```
10 INPUT M
11 INPUT N
```

LET

Some BASICs allow you to omit the word LET ;

```
10 A=B
```

is treated as if it were;

```
10 LET A=B
```

LEFT$, MID$, RIGHT$

These functions occur in many versions of BASIC. They operate on a string, returning a part of that string.

LEFT$(X$,Y) gives the first Y characters in X$, it's ZX81 equivalent is X$(TO Y)

RIGHT$(X$,Y) gives the rightmost Y characters from X$, and translates to X$(LEN X$-Y+1 TO)

MID$(X$,Y,Z) gives Z characters from X$, starting at the Yth. character of X$. It is equivalent to X$(Y TO Y+Z-1).

PRINT

PRINT statements will often have to be changed to make best use of the ZX81 screen format. Note that programs not written for the ZX81 may assume that the print-out is to be done on a display which automatically scrolls as required, and may need changing to prevent a display area overflow.

PEEK , POKE , USR , CALL , LINK , ?

LINK and CALL are similar to USR in that they call a machine language routine, but they do not return a value to the calling BASIC program. '?' is used in a highly exotic way by the Acorn Atom for both PEEK and POKE.

The effect of these commands depends entirely on the particular machine being used. To convert a program containing any of these

to run on the ZX81 you must find out exactly what the command was intended to do, then write ZX81 code to perform a similar function.

RND

Some BASICs need RND to be followed by a number enclosed in brackets, e.g; LET A=RND(1).
This number can be omitted in ZX81 BASIC, except where the program was written for a BASIC which handles only integer values (such as 4K ZX80 BASIC). In these cases, RND(n) usually gives a random integer value between 1 and n, or between 0 and n-1.

String concatenation

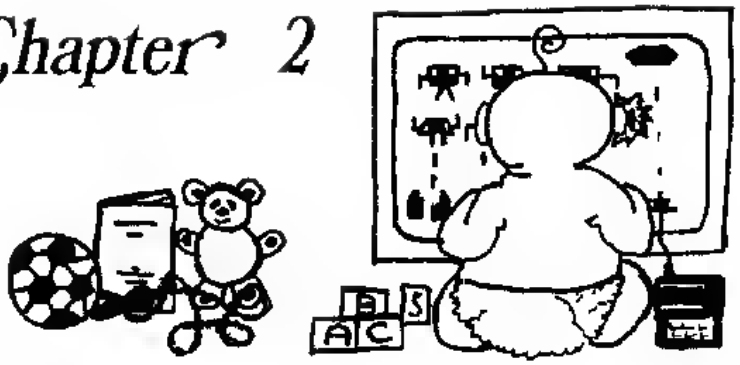
Some BASICs use the symbol '&' or '!' to join two strings, e.g;

```
LET A$=B$ & C$     or     LET A$=B$ ! C$
```

which are equivalent to the ZX81's;

```
LAT A$=B$+C$
```

Chapter 2



Some Games, and Other Novelties

24 Weekday
25 Dynamite
27 Sums Tester
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34 Fencing
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44 Recipes
45 SAM
46 Cambridge Crypto
46 CR?S??ORD
47 Starburst
48 RAMtest
48 ROMtest

Weekday

This program calculates the day of the week for any date after 1750 AD (except for Russia, which did not change to the Gregorian calendar until 1917).

Monday's child is fair of face,
Tuesday's child is full of grace.
Wednesday's child is full of woe,
Thursday's child has far to go.
Friday's child is loving and giving,
Saturday's child works hard for a living.
But the child that's born on the Sabbath day
Is bonny, blithe, and good, and gay.

```
 10 DIM K(12)
 20 LET A$="033614625035"
 30 FOR A=1 TO 12
 40 LET K(A)=CODE A$(A)-CODE "0"
 50 NEXT A
 60 LET A$="SUNDAY   MONDAY   TUESDAY  WEDNESDAYTHURSDAY
    FRIDAY   SATURDAY "
100 CLS
110 PRINT "YEAR ?"
120 INPUT Y
130 PRINT AT 0,5;Y,,"MONIH (1-12) ?"
140 INPUT M
150 PRINT AT 1,6;M;"       ",,"DAY ?"
160 INPUT D
170 PRINT AT 2,4;D
200 LET B=Y-100*INT (Y/100)
210 LET X=INT (Y/100)-15
220 LET A=3+X*21
230 LET I=INT ((A-28*INT (A/28))/4)
240 LET A=B*5+4*(D+K(M)+I)
250 LET W=1+INT ((A-28*INT (A/28))/4)
260 IF M>2 THEN GOTO 320
270 LET L=X-1+4*INT ((X-1)/4)
280 IF B>0 THEN LET L=Y-4*INT(Y/4)
290 IF L>0 THEN GOTO 320
300 IF W=0 THEN LET W=6
310 LET W=W-1
320 IF W=0 THEN LET W=7
330 PRINT AT 4,0;"IS A ";A$(9*W-8 TO 9*W)
```

There should be exactly 54 characters including spaces between the quotation marks in line 60.

Dynamite

The game starts with a row of very old, very dangerous, sticks of dynamite. You and the ZX81 take turns to remove them, but only 1,2 or 3 sticks may be taken at a time. The last stick will explode, so the player left with this one loses !

```
 10 REM DYNAMITE
 20 SLOW
100 GOSUB 2000
110 RAND
120 LET D=21+INT (12*RND)
130 LET S=0
140 FOR A=0 TO D-1
150 FOR B=9 TO 6 STEP -1
160 PRINT AT B,A;"▯"
170 NEXT B
180 NEXT A
190 PRINT AT 14,0;D;" STICKS OF DYNAMITE"

200 PRINT AT 16,0;"HOW MANY STICKS WILL YOU TAKE ?"
210 LET T=CODE INKEY$-28
220 IF T<1 OR T>3 OR T>D THEN GOTO 210
230 PRINT AT 16,0;S$;AT 16,0;"YOU TAKE ";T
240 LET D=D-T
250 FOR A=S+D+T TO S+D STEP -1
260 FOR B=6 TO 9
270 PRINT AT B,A;" "
280 NEXT B
290 NEXT A

300 PRINT AT 14,0;D;" ";AT 14,22;"LEFT"
310 IF D=0 THEN GOTO 700
320 IF D=1 THEN GOTO 800
330 PRINT AT 16,0;"PRESS ANY KEY FOR MY TURN;S$
340 IF INKEY$="" THEN GOTO 330
350 LET R=D-4*INT (D/4)
360 LET C=R+3-4*INT ((R+3)/4)
370 IF R=1 THEN LET C=1+INT (3*RND)
380 LET D=D-C
390 PRINT AT 16,0;S$;AT 16,0;"I TAKE ":C

400 FOR A=S TO S+C-1
410 FOR B=6 TO 9
420 PRINT AT B,A;" "
430 NEXT B
```

```
440 NEXT A
450 PRINT AT 14,0;D;" "
460 LET S=S+C
470 IF D=0 THEN GOTO 800
480 IF D=1 THEN GOTO 700
490 GOTO 200

700 GOSUB 1000
710 PRINT AT 16,0;"*** I WIN ***";AT 18,0;X$(INT (1+5*RND))
720 GOTO 900

800 GOSUB 1000
810 PRINT AT 16,0;"** YOU HAVE WON **";AT 18,0;Y$(INT (1+5*RND))

900 PRINT AT 20,0;"ANOTHER GAME ?"
910 IF INKEY$="N" THEN STOP
920 IF INKEY$<>"Y" THEN GOTO 910
930 CLS
940 RUN

1000 LET A=6
1010 PRINT AT 14,0;S$;AT 16,0;S$;AT 7,S;" ";AT 8,S;" ";AT 9,S;" "
1020 FOR B=0 TO A
1030 PRINT AT A-B,S-B;"*";AT A+B,S-B;"*";AT A+B,S+B;"*";AT A-B,
     S+B;"*"
1040 NEXT B
1050 FOR B=0 TO A
1060 PRINT AT A-B,S-B;" ";AT A+B,S-B;" ";AT A+B,S+B;" ":AT A-B,
     S+B;" "
1070 NEXT B
1080 RETURN

2000 DIM X$(5,32)
2010 DIM Y$(5,32)
2020 DIM S$(32)
2030 LET X$(1)="WHAT A CLEVER COMPUTER I AM"
2040 LET X$(2)="**** ZX RULES, OK ? ****"
2050 LET X$(3)="HOW ABOUT THAT THEN"
2060 LET X$(4)="- OF COURSE."
2070 LET X$(5)="WHY DONT YOU GIVE UP ?"
2080 LET Y$(1)="** CONGRATULATIONS **"
2090 LET Y$(2)="I BET YOU CHEATED"
2100 LET Y$(3)="I WILL GET YOU NEXT TIME"
2110 LET Y$(4)="OF COURSE I LET YOU"
2120 LET Y$(5)="WHAT LUCK"
2130 RETURN
```

The actual calculations involved in this program are relatively simple, most of the program being devoted to giving an interesting display as the game progresses. Note how lines 710,810 give a variable response at the end of the game; the comments in lines 2000-2130 may of course be changed to suit the temperament of your particular ZX81.

Sums Tester 1K

And now to prove that the ZX81 has an educational value; SUMS TESTER provides an excercise in simple addition.

It poses 10 questions of the form A + B = ? , and displays a running total of the correct answers. At the end of the ten questions, it also shows the total time taken to answer.

```
 1Ø RAND
 2Ø LET S=Ø
 3Ø LET T=S
1ØØ FOR G=1 TO 1Ø
11Ø PRINT ,,"PRESS Y·FOR QUESTION ";G
12Ø IF INKEY$<>"Y" THEN GOTO 12Ø
13Ø CLS
14Ø LET A=INT (99*RND+1)
15Ø LET B=INT (99*RND+1)
16Ø POKE 16436,255
17Ø POKE 16437,255
18Ø PRINT ,,A;" + ";B;" = ?"
19Ø INPUT C
2ØØ LET T=T+65535-PEEK 16436-256*PEEK 16437
21Ø IF C=A+B THEN GOTO 24Ø
22Ø PRINT ,,C;" IS WRONG, THE ANSWER IS ";A+B
23Ø GOTO 3ØØ
24Ø PRINT ,,C;" IS RIGHT"
25Ø LET S=S+1
3ØØ PRINT ,,"SCORE = ";S
31Ø NEXT G
32Ø PRINT ,,"YOU TOOK ";INT (T/5Ø);" SECONDS"
```

U.S. readers should change '50' in line 320 to '60'.

As given the program only asks questions of addition, with numbers from 1 to 99. Why not modify it for subtraction, multiplication, or division, or to use a smaller or larger range of numbers ?

ZX Sofft Shoppes

How do you rate your chances as a Super Software Salesman ? This program gives you the chance to try running your own business. It can be played by one individual, or - better - by several competing players.

The program gives you successive months in the life of a typical software shop. At the start of each month you have an amount of cash, and unsold stock left over from the previous months. You have to decide how much to spend on advertising, how much on new stock, and what mark-up to apply (Mark-up is selling price divided by cost, thus if you buy some software for 1.00 and sell it for 1.50 your 'mark-up' is 1.5).

At the end of each 'month', the ZX Sofft Shoppe computer shows you the sales for the month - in terms of both stock value (what you paid for it) and selling price.It then displays the value of the remaining stock and your latest cash position.

Tax is payable in January on the previous year's profits. If you can't pay your tax bill then you are declared bankrupt and out of the game. As an aid to budgetting, the current tax liability for the year to date is included in each month's results; if no tax liability is shown then you are making a loss !

The business model used by the program gives higher sales around Christmas, and lower than average sales in the summer months. Both advertising expenditure and mark-up will affect your sales, as will competition from other shops. To maximise each month's sales you should keep a balance between old and new stock.

Have fun. Anyone tripling his initial investment in the first year is invited to apply to Timedata for an interesting job !

```
 100 PRINT AT 5,4;"YE ZX SOFFT SHOPPES"
 110 GOSUB 5000

1000 FOR X=1 TO N
1010 CLS
1020 PRINT N$(X)
1030 IF M=0 THEN GOTO 1600

1100 PRINT AT 2,0;"RESULTS FOR ";M$(M);AT 2,23;Y
1110 LET E=A(X,1)+A(X,2)+A(X,3)+A(X,5)
1120 LET B=INT ((3+RND)*A*A(X,5)/(A(X,4)**3))
1130 LET C=INT (B*(1+RND)*.5)
1140 IE B>A(X,3) THEN LET B=A(X,3)
1150 IF C>A(X,2)THEN LET C=A(X,2)
1160 LET A(X,2)=A(X,2)-C+A(X,3)-B
1170 LET A(X,3)=0
1180 LET D=INT ((B+C)*A(X,4))
1190 LET A(X,1)=A(X,1)+D

1200 LET T=(A(X,1)+A(X,2)-F)*.3
1210 PRINT AT 4,0;B+C;"  STOCK SOLD FOR";TAB 24;D
```

```
1220 IF M>1 OR Y=1982 THEN GOTO 1540
1230 IF A(X,6)<=A(X,1) THEN GOTO 1500

1300 PRINT AT 5,0;"TAX DUE";TAB 24;A(X,6)
1310 PRINT AT 7,0;"BUT YOU HAVE ONLY";TAB 24;A(X,1)
1320 PRINT AT 9,0;"SO YOU ARE BANKRUPT,"
1330 PRINT "AND OUT OF THE GAME."
1340 IF N=1 THEN STOP

1400 IF X=N THEN GOTO 1470
1410 FOR B=X TO N-1
1420 FOR C=1 TO 6
1430 LET A(B,C)=A(B+1,C)
1440 NEXT C
1450 LET N$(B)=N$(B+1)
1460 NEXT B
1470 LET N=N-1
1480 LET X=X-1
1490 GOTO 1999

1500 IF A(X,6)<0 THEN LET A(X,6)=0
1510 PRINT AT 5,0;"TAX PAID;";TAB 24;INT A(X,6)
1520 LET A(X,1)=A(X,1)-INT A(X,6)
1530 LET A(X,6)=0
1540 LET A(X,6)=A(X,6)+T

1600 PRINT AT 7,0;"YOU NOW HAVE;";TAB 18;"CASH";TAB 24;A(X,1);
     TAB 18;"STOCK";TAB 24;A(X,2)
1610 IF A(X,6)>0 THEN PRINT AT 10,0;"TAX DUE NEXT JANUARY;";
     TAB 24;INT A(X,6)
1620 LET U=M+1
1630 LET V=Y
1640 IF U<13 THEN GOTO 1670
1650 LET U=1
1660 LET V=V+1
1670 PRINT AT 13,0;"DECISIONS FOR ";M$(U);AT 13,23;V

1700 PRINT AT 15,0;"HOW MUCH WILL YOU SPEND;";TAB 9;"ON ADVE
     RTISING ?"
1710 INPUT I
1720 LET I=INT I
1730 IF I<0 OR I>A(X,1) THEN GOTO 1710
1740 LET A(X,5)=I
1750 LET A(X,1)=A(X,1)-I
1760 PRINT AT 16,24;I
1770 PRINT AT 17,15;"ON STOCK ?"
1780 INPUT I
1790 LET I=INT I

1800 IF I<0 OR I>A(X,1) THEN GOTO 1780
1810 LET A(X,3)=I
1820 LET A(X,1)=A(X,1)-I
1830 PRINT AT 17,24;I
1840 PRINT "MARKUP (PRICE/COST)     ?"
1850 INPUT I
1860 IF I<0 THEN GOTO 1850
```

```
1870 LET A(X,4)=I
1880 PRINT AT 18,24;I

1900 PRINT AT 21,0;"DO YOU WANT TO CHANGE ANYTHING ?"
1910 INPUT I$
1920 IE (I$+Z$)(1)="N" THEN GOTO 1999
1930 EOR I=15 TO 21
1940 PRINT AT I,0;Z$
1950 NEXT I
1960 LET A(X,1)=A(X,1)+A(X,5)+A(X,3)
1970 GOTO 1700
1999 NEXT X

2000 LET A=0
2010 FOR X=1 TO N
2020 LET A=A+A(X,4)
2030 NEXT X
2040 LET A=SQR (A/N)

2100 LET M=M+1
2110 IE M<13 THEN GOTO 1000
2120 LET M=1
2130 LET Y=Y+1
2140 GOTO 1000

5000 REM INITIALISATION
5010 DIM M$(12,11)
5020 LET M$(1)="JANUARY"
5030 LET M$(2)="FEBRUARY"
5040 LET M$(3)="MARCH"
5050 LET M$(4)="APRIL"
5060 LET M$(5)="MAY"
5070 LET M$(6)="JUNE"
5080 LET M$(7)="JULY"
5090 LET M$(8)="AUGUST"
5100 LET M$(9)="SEPTEMBER"
5110 LET M$(10)="OCTOBER"
5120 LET M$(11)="NOVEMBER"
5130 LET M$(12)="DECEMBER"
5140 LET Y=1982
5150 LET M=0
5160 DIM Z$(32)

5200 PRINT AT 15,0;"NUMBER OF SHOPS (PLAYERS) ?"
5210 INPUT N
5220 DIM N$(N,32)
5230 DIM A(N,6)
5240 FOR X=1 TO N
5250 PRINT AT 15,0;Z$;AT 15,0;"NAME OF SHOP ";X
5260 INPUT N$(X)
5270 LET A(X,1)=100
5280 NEXT X
5290 RETURN
```

Copycat 1K

In this version of the well known childrens' game, a sequence of letters is flashed onto the TV screen. You are then invited to key in the same sequence. This happens ten times, each time with a longer sequence, and your score of correct responses is shown. When the game starts you can choose the speed at which the letters are shown; from 1 (boring) to 5 (impossible ?). After each go, press key 'Y' for the next sequence, or BREAK to quit.

```
 10 SLOW
 20 LET C=0
 30 PRINT "SPEED (1-5)"
 40 INPUT S
 50 LET S=55-(S AND S>=1 AND S<=5)*10

100 FOR G=1 TO 10
110 CLS
120 LET A$=""
130 FOR B=1 TO G+1
140 LET C$=CHR$ (38+25*RND)
150 PRINT AT 1,1;C$
160 LET A$=A$+C$
170 FOR X=1 TO S
180 NEXT X
190 PRINT AT 1,1;" "

200 FOR X=1 TO 10
210 NEXT X
220 NEXT B

300 PRINT "WHAT WERE THEY ?"
310 INPUT C$
320 PRINT C$
330 IF C$<>A$ THEN GOTO 370
340 PRINT "CORRECT"
350 LET C=C+1
360 GOTO 390
370 PRINT "WRONG, THEY WERE;"
380 PRINT A$
390 PRINT AT 7,1;C;" OUT OF ";G;(" NEXT GO ?" AND G<10)

400 PRINT "WELL DONE" AND C=10
410 IF G=10 THEN STOP
420 IF INKEY$<>"Y" THEN GOTO 420
430 NEXT G
```

Note that FOR-NEXT loops are used to generate delays in the program (lines 170,180,200,210) rather than the ZX81 PAUSE command, which can give an annoying flicker in this type of application.

BINDECHEX 1K

This program will accept a binary, hexadecimal, or decimal number and display it in all three forms.

Binary numbers can be up to 16 digits long, and should be entered starting with the letter 'B' ;

B1ØØ111ØØ

Hexadecimal numbers can be up to 4 digits long and should be entered starting with 'H';

HFF1A

Decimal numbers can be from Ø to 65535, and should start with the letter 'D';

D4Ø96

The program will keep asking for more numbers to convert until you enter a null line (just press NEWLINE/ENTER).

```
 1Ø LET Z=PI-PI
 2Ø LET U=PI/PI
 3Ø LET T=U+U
 4Ø LET F=T+T
 5Ø LET S=F*F

1ØØ PRINT AT F,Z;"ENTER NUMBER PREFIXED";TAB F;"B IF BINARY"
    ;TAB F;"D IF DECIMAL";TAB F;"H IF HEX"
11Ø INPUT I$
12Ø IF I$="" THEN STOP
13Ø LET T$=I$(U)
14Ø LET X=(T AND T$="B")+(1Ø AND T$="D")+(S AND T$="H")
15Ø IF X=Z THEN GOTO 11Ø
16Ø CLS

2ØØ LET D=Z
21Ø FOR A=T TO LEN I$
22Ø LET D=D*X+CODE I$(A)-28
23Ø NEXT A

3ØØ PRINT " DEC   HEX      BINARY";AT T,Z;D
31Ø LET E=D
32Ø FOR A=U TO F
33Ø PRINT AT T,1Ø-A;CHR$ (CODE "Ø"+E-S*INT (E/S))
34Ø LET E=INT (E/S)
35Ø NEXT A
36Ø FOR A=U TO S
37Ø PRINT AT T,27-A;CHR$ (CODE "Ø"+D-T*INT (D/T))
38Ø LET D=INT (D/T)
39Ø NEXT A

4ØØ GOTO 1ØØ
```

The program first converts whatever form of number is entered to the decimal equivalent D, then prints that and the hex and binary versions - calculating them as it goes (lines 320-390).

It just squeezes into 1K ; note lines 10-50 which remove the need for RAM consuming constants Ø,1,2,4 and 16 throughout the program.

Why not try modifying the program to work in other bases, say Octal (base 8) or Ternary (base 3) ?

Roman – Arabic 1K

This program accepts a number written in Roman numerals (for example MCMLXXXII) and converts it to our modern Arabic numeral form. Having converted one number, it will ask for another ; enter a null line (just press NEWLINE/ENTER) to end.

Note that the Roman numerals are the letters M,D,C,L,X,V and I. The program will not accept the Arabic numeral '1'.

```
 1Ø PRINT AT 5,Ø;"ENTER ROMAN FORM OF NUMBER"
 2Ø LET P=Ø
 3Ø INPUT D$
 4Ø IF D$="" THEN STOP
 5Ø CLS
 6Ø LET Y=P
 7Ø FOR A=LEN D$ TO 1 STEP-1
 8Ø FOR B=1 TO 7
 9Ø IF D$(A)="IVXLCDM"(B) THEN GOTO 13Ø
1ØØ NEXT B
11Ø PRINT D$;" NOT VALID"
12Ø GOTO 1Ø
13Ø LET V=VAL "ØØ1ØØ5Ø1ØØ5Ø1ØØ5ØØ1E3"(B*3-2 TO B*3)
14Ø LET Y=Y+(V AND B>=P)-(V AND B<P)
15Ø IF B>P THEN LET P=B
16Ø NEXT A
17Ø PRINT D$;" = ";Y
18Ø GOTO 1Ø
```

Note how line 90 provides a fixed set of characters, and line 130 similarly provides a fixed set of numbers.

Arabic–Roman 1K

This program converts our customary arabic numbers to their Roman equivalents, e.g;

1982 to MCMLXXXII

After converting one number, it asks for another. Enter STOP to quit.

```
 2 PRINT AT 5,Ø;"ENTER NUMBER"
 4 INPUT N
66 CLS
 8 PRINT N;" = ";
1Ø FOR A=1 TO 7
12 LET B=VAL "1E35ØØ1ØØØ5ØØ1ØØØ5ØØ1"(3*A-2 TO 3*A)
14 IF N<B THEN GOTO 22
16 PRINT "MDCLXVI"(A);
18 LET N=N-B
2Ø GOTO 12
22 LET C=VAL "1ØØ1ØØØ1ØØ1ØØØ1ØØ1ØØØ"(3*A-2 TO 3*A)
24 IF N<B-C THEN GOTO 32
26 PRINT "CCXXIII"(A);
28 LET N=N+C
3Ø GOTO 12
32 NEXT A
34 GOTO 2
```

Note how lines 12,16,22 and 26 provide fixed sets of numbers.

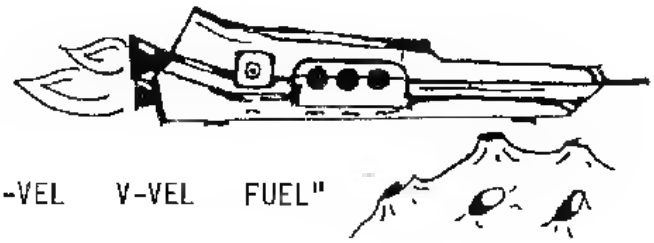
Fencing 1K

This program draws a sequence of basket-weave patterns. Use the BREAK key to stop it.

```
 1Ø SLOW
 2Ø LET H=1
 3Ø LET V=1
 4Ø LET X=54*RND
 5Ø LET Y=Ø
1ØØ FOR I=1 TO 5ØØ
11Ø PLOT X,Y
12Ø LET H=H-(2 AND X>54)+(2 AND X<1)
13Ø LET V=V-(2 AND Y>3Ø)+(2 AND Y<1)
14Ø LET X=X+H
15Ø LET Y=Y+V
16Ø NEXT I
2ØØ CLS
21Ø RUN
```

Moonlander

You are piloting a rocket ship about to land on the Moon (the @@@*** auto-landing computer has failed again !). At the start of the game you are at a height of 370 metres, travelling horizontally at 30 metres per second, and just starting to come out of orbit and fall towards the Moon's surface. You can control the ship by pressing keys 5 and 7 (one at a time) to apply left or vertical thrust respectively. Try to land as near as possible to the white square at the bottom of the screen with a vertical velocity of less than 3 metres per second. And watch your fuel !



```
100 LET A=370
110 LET H=30
120 LET V=0
130 LET F=55
140 LET P=0

200 PRINT "HEIGHT  H-VEL   V-VEL   FUEL"
210 FOR I=0 TO 63
220 PLOT I,0
230 NEXT I
240 UNPLOT 32,0

300 FOR I=1 TO 1E9
310 PLOT P,A/10
320 PRINT AT 1,0;A;" ";TAB 8;H;" ";TAB 16;V;" ";TAB 24;F;" "
330 IF A<1 OR P<0 OR P>63 THEN GOTO 1000
340 LET A$=INKEY$
350 IF F<=0 THEN GOTO 400
360 LET V=V+1-(2 AND A$="7")
370 LET H=H-(A$="5")
380 LET F=F-(A$="7" OR A$="5")

400 LET A=A-V
410 LET P=P+H/25
420 NEXT I

1000 IF ABS V<3 THEN PRINT AT 10,0;"A SAFE LANDING"
1010 IF ABS V>=3 AND ABS V<5 THEN PRINT AT 10,0;"BUMPY, BUT WE
     ARE STILL ALIVE"
1020 IF ABS V>=5 THEN GOTO 1100
1030 IF ABS (P-32)>=3 THEN PRINT "A LONG WAY FROM BASE"
1040 IF ABS (P-32)>=6 THEN PRINT "WHICH COUNTRY IS THIS THEN ?"
1050 IF ABS V<3 AND ABS (P-32)<3 THEN PRINT "HELLO BUCK ROGERS"
1060 STOP
1100 PRINT AT 10,0;"ANOTHER CRATER"
```

Note how lines 340,360 and 370 vary the vertical velocity V, the horizontal velocity H and the fuel remaining F according to whether keys 5 or 7 are pressed. You could expand this section of the program to give right thrust by detecting key 8.

Decimal Peeker

The following simple program will list out the contents of any 22 consecutive memory locations (ROM or RAM). Enter the address you want the list to start at, and the program will display the 22 addresses with the contents of these locations in decimal.

When the screen is full the program will stop with the report 5/4Ø , allowing you to enter COPY to get a permanent record on the ZX printer, CONT to display the next 22 locations, or quit.

```
1Ø PRINT "ADDR ?"
2Ø INPUT A
3Ø CLS
4Ø PRINT A;"  ";PEEK A
5Ø LET A=A+1
6Ø GOTO 4Ø
```

The program is very useful for examining how programs are stored by the ZX81 in RAM. If you add a test line, say;

```
5 LET A=5
```

and then RUN the program, giving it the starting address 165Ø9 (the start of the ZX81's program storage area),you will get;

```
16509  Ø   ┐
16510  5   ┘ line number 5  (Ø * 256 + 5)
16511  11  ┐ number of bytes following in this line
16512  Ø   ┘ (11 + Ø * 256)
16513  241   LET
16514  38    A
16515  2Ø    =
16516  33    5
16517  126   "the next 5 bytes are a binary number"
16518  131 ┐
16519  32  │
16520  Ø   │
16521  Ø   │ floating point binary version
16522  Ø   ┘ of the number 5
16523  118   NEWLINE
```

Or, you can look at the Display File by entering

```
PEEK 16396 + 256*PEEK 16397
```

as the start address ; the ZX81 can accept any valid expression as a response to an INPUT statement, this expression gives the current value of D-FILE; which is the address of the start of the Display File area of RAM. If the program has been entered exactly as shown, the result will be;

```
16581  118   NEWLINE - always present at start of display file
16582  29    1
16583  34    6
16584  33    5
16585  36    8
```

```
16586  29    1
16587  Ø     space
16588  29    1
16589  29    1
16590  36    8
16591  118   NEWLINE, end of first line of display
   --
```

Note that if you have more than 3 1/2 K of RAM, then the first line will be padded out with spaces (code Ø) to give a total of 32 characters before the NEWLINE code 118.

In this example output, the program is effectively displaying what it has already printed out ("16581 118" etc), but by adding a test line 5 to the program, you can see what that does to the Display File.

Variable Peeker

The program DECIMAL PEEKER can't be used as it stands to look at the variables area of RAM because the variables area keeps moving as the Display File is added to (at least, on a ZX81 with less than 3 1/2 K of RAM). To overcome this problem, the program has to re-calculate its reference point in the variables area for each value, resulting in the new program;

```
1Ø LET A=Ø
2Ø PRINT A;TAB 5;PEEK (A+PEEK 164ØØ+256*PEEK 164Ø1)
3Ø LET A=A+1
4Ø GOTO 2Ø
```

Adding a test line;

```
5 LET B=5
```

will give an output;

```
Ø    1Ø3    B (CODE "B" + 64)
1    131 ⎫
2    32  ⎪
3    Ø   ⎪  Binary floating point '5'
4    Ø   ⎪
5    Ø   ⎭
6    1Ø2    A (CODE "A" + 64)
     --
```

Now try changing the test line 5 to set up a string variable, or an array, or a numeric variable with a multi-character name. Chapter 27 of the Sinclair ZX81 BASIC manual should help you to interpret the results.

Hex Peeker

This program lets the hexadecimal enthusiast examine the contents of the ZX81's ROM and RAM locations.

When RUN it asks for a starting address - which must be given in hexadecimal - and it then displays the contents of 22 consecutive locations, giving the addresses and the contents in hexadecimal form.

It will stop with the report 5/310 , allowing you to enter COPY to get a hard copy on the ZX printer, CONT to display the next 22 locations, or STOP to quit.

```
100 PRINT "ADDRESS ?"
110 INPUT A$
120 CLS
130 LET A=0
140 FOR B=1 TO LEN A$
150 LET A=16*A+CODE A$(B)-CODE "0"
160 NEXT B

200 LET B=INT (A/256)
210 GOSUB 300
220 LET B=A-B*256
230 GOSUB 300
240 PRINT "  ";
250 LET B=PEEK A
260 GOSUB 300
270 PRINT
280 LET A=A+1
290 GOTO 200

300 LET C=INT (B/16)
310 PRINT CHR$ (C+CODE "0");CHR$(B-16*C+CODE "0");
320 RETURN
```

As an example, if you enter the starting address 0, the program will display the beginning of the ZX81's ROM;

```
0000  D3
0001  FD
0002  01
0003  FF
      --
```

This program is one of the few in this book to use subroutines effectively.

Things

?? =

You think of the name of a 'thing', the computer then tries to find out what it is by asking a series of questions.

If the computer doesn't know what you are thinking of, it will eventually give up and ask you what it was, and for a question that it can ask in future to distinguish this new 'thing' from the computer's guess (each question must have a simple Yes/No answer; "Does it have 4 legs" is a valid type of question but "How many legs has it" is not). In this way the computer can build up it's store of 'knowledge' as you play by adding to a data file, which can be saved on tape for future sessions.

This data file can be constructed around virtually any subject by a suitable choice of questions and answers; why not try to construct one for simple automobile fault diagnosis, or whatever your imagination suggests. It is saved on tape as part of the program - as usual with ZX81 data files - and you can choose the name it is filed under at the time of saving it, so different data files can be generated by the program. To use the file later, just LOAD as normal. If you want to delete the current data file from the program in RAM, just stop it with the BREAK key, then RUN to start it again but with an empty data bank.

```
 1Ø REM THINGS
 2Ø LET A=9999
 3Ø DIM A$(A)
 4Ø LET A$(1 TO 2Ø)="QØ9ØØ21ØØ37IS IT BIG"
 5Ø LET A$(21 TO 36)="T13SPACE SHUTTLE"
 6Ø LET A$(37 TO 43)="TØ4ZX81"
 7Ø LET F=44

1ØØ CLS
11Ø LET P=1
12Ø PRINT AT 8,8;"THINK OF A THING.";AT 11,13;"READY ?"
13Ø IF INKEY$<>"Y" THEN GOTO 13Ø

2ØØ CLS
21Ø LET L=VAL (A$(P+1 TO P+2))
```

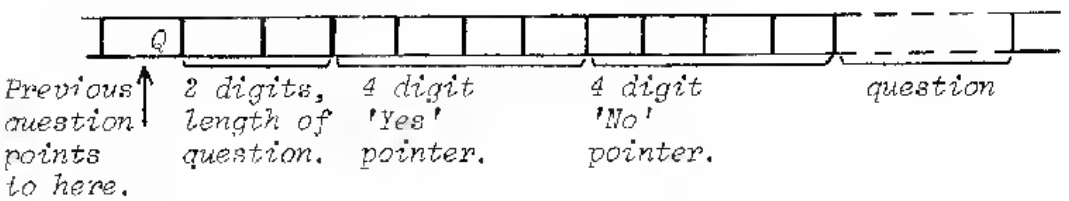
```
220 IF A$(P)="T" THEN GOTO 300
230 PRINT AT 8,0;A$(P+11 TO P+10+L);" ?"
240 GOSUB 1000
250 LET Q=P+3+(4 AND I$="N")
260 LET P=VAL A$(Q TO Q+3)
270 GOTO 200

300 PRINT AT 8,0;"IS IT A";AT 10,0;A$(P+3 TO P+2+L);" ?"
310 GOSUB 1000
320 IF I$="N" THEN GOTO 400
330 PRINT AT 12,0;"I GUESSED IT, WHAT A CLEVER ZX81"
340 GOTO 800

400 PRINT AT 13,0;"WHAT WAS IT THEN ?"
410 INPUT T$
420 CLS
430 PRINT AT 6,0;"WHAT QUESTION DISTINGUISHES A"
440 PRINT AT 8,0;A$(P+3 TO P+2+L);TAB 1;TAB 0;"FROM A";
     TAB 1;TAB 0;T$;" ?"
450 INPUT Q$
460 PRINT AT 14,0;Q$
470 IF F+LEN T$+LEN Q$>A THEN GOTO 950
480 PRINT

500 PRINT "IS THE ANSWER Y OR N FOR A";TAB 0;T$;" ?"
510 GOSUB 1000
515 CLS
520 LET X=F
530 GOSUB 1100
540 LET A$(Q TO Q+3)=X$
550 LET X=LEN Q$
560 GOSUB 1100
570 LET A$(F TO F+10+X)="Q"+X$(3 TO)+"12345678"+Q$

600 LET X=P
610 GOSUB 1100
620 LET P$=X$
630 LET Q=F
640 LET F=F+LEN Q$+11
650 LET X=F
660 GOSUB 1100
670 LET X$=X$+P$
680 IF I$="N" THEN LET X$=X$(5 TO )+X$( TO 4)
690 LET A$(Q+3 TO Q+10)=X$

700 LET X=LEN T$
710 GOSUB 1100
720 LET A$(F TO F+X+2)="T"+X$(3 TO )+T$
730 LET F=F+X+3

800 PRINT AT 20,0;"ANOTHER GO ?"
810 GOSUB 1000
820 IF I$="Y" THEN GOTO 100
830 CLS
840 PRINT AT 20,0;"DO YOU WANT TO SAVE THIS DATA ?"
850 GOSUB 1000
860 CLS
```

```
870 IF I$="N" THEN STOP
880 PRINT AT 18,0;"TAPE FILE NAME ?"
890 INPUT T$

900 PRINT AT 20,0;"START RECORDER,THEN PRESS Y"
910 GOSUB 1000
920 SAVE T$
930 GOTO 100
950 PRINT AT 19,0;"MY MEMORY IS FULL"
960 GOTO 800

1000 LET I$=INKEY$
1010 IF I$<>"Y" AND I$<>"N" THEN GOTO 1000
1020 RETURN

1100 LET X$="0000"+STR$ X
1110 LET X$=X$(LEN X$-3 TO )
1120 RETURN
```

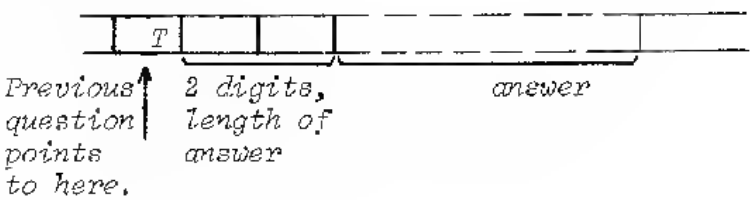
This program illustrates the use of a 'tree' structure for data storage. Each question stored has two associated pointers which give the locations of the next logical questions for 'Y' and 'N' responses. The program simply moves from one question to the next according to each 'Y' or 'N' response until it reaches a possible answer. If this answer is not correct, the correct answer is obtained from the user, together with a new question. These are stored in the first available free memory space, then the pointers are altered to reflect these additions.

The questions and answers are actually stored in a single dimensioned character array A$(); new items being added onto the end of the previous data, in 'linked list' form. This is an efficient way of storing a lot of variable length data, although it may not be the best solution for programs which need to access individual data elements quickly as to find any particular item the program has to search through the list from the beginning.

Questions are stored as;



and answers as;



See lines 40,50 & 60 for examples.

BUZZ 1K

An aid for the busy executive, BUZZ generates impressive sounding phrases for use in reports to higher management. Or it could be used for writing newspaper headlines, or for choosing names for the characters in TV plays, depending on the data entered.

This data consists of 30 words or phrases (not more than 10 characters each), numbered 1 to 31. They are divided into three groups, numbers 1 to 10, 11 to 20 and 21 to 30. The program prints one word or phrase from each group in turn, selecting them at random.

When the program is first RUN, you should enter the 30 words or phrases in turn, the number of the phrase to be entered is displayed as a prompt each time.

After all 30 words or phrases have been entered, the program will display the first of it's compositions. It will generate another one if you press the "Y" key, pressing any other key will stop the program, giving report 9/210 . CONT will then save the program (complete with the data you have entered) to tape with the name "BUZZ" - change line 220 if you prefer another name - so that when it is subsequently LOADed from tape the program will automatically run using the data that has been entered previously.

A suitable list of words is;

1 GLOBAL	11 SILICON	21 TECHNOLOGY
2 ECOLOGICAL	12 TOP DOWN	22 PROJECTION
3 PARALLEL	13 PRAGMATIC	23 PHASE
4 VALID	14 MODULAR	24 SCENARIO
5 FEASIBLE	15 REDUNDANT	25 PROJECT
6 COMMON	16 SUPPORTIVE	26 TARGET
7 INFORMED	17 REFINED	27 RULING
8 LOCAL	18 VIDEO	28 FACTORS
9 INTERIM	19 NETWORKED	29 OPTIONS
10 VISIBLE	20 PROGRAMMED	30 COMMENTARY

but why not make your own lists ?

```
 10 DIM A$(30,10)
 20 FOR I=1 TO 30
 30 PRINT I
 40 INPUT A$(I)
 50 CLS
 60 NEXT I
100 FOR I=1 TO 21 STEP 10
110 LET B$=A$(I+INT (10*RND))+" "
120 LET B$=B$( TO LEN B$-1)
130 IF B$(LEN B$)=" " THEN GOTO 120
140 PRINT B$;" ";
150 NEXT I
160 PRINT
```

```
170 PRINT "ANOTHER ?"
180 IF INKEY$="" THEN GOTO 180
190 CLS
200 IF INKEY$="Y" THEN GOTO 100
210 STOP
220 SAVE "BUZZ"
230 GOTO 100
```

As well as being fun to use, this program also illustrates one way of storing fixed data in a ZX81 program when space is limited, and the use of a SAVE statement within a program.

Bob-Sleigh 1K

How good are you at steering a bob-sleigh down a twisting course ? Well, here's your chance to find out. Use keys 5 & 8 to steer, but be careful because the course gradually gets narrower!

```
 10 SLOW
 20 LET A=5
 30 LET B=12
 40 LET E=15
100 FOR X=8 TO 3 STEP -.03
110 PRINT AT E,B;" "
120 SCROLL
130 LET C=INT (A+A*SIN (X*A))
140 LET D$=INKEY$
150 LET B=B-(1 AND D$="5")+(1 AND D$="8")
160 PRINT AT E,C;"■"
170 PRINT AT E,C+X;"■"
180 PRINT AT E,B;"V"
190 IF B<=C OR B>=C+X THEN GOTO 300
200 NEXT X
210 PRINT AT 16,C;"END"
220 STOP
300 PRINT AT E,B;"CRASH"
```

This program features the SCROLL command, used here to give a 'moving' display. The other feature that may be of interest is the way lines 140 & 150 control the variable B (the position of the bob sleigh) in response to keys 5 and 8; pressing key 5 decrements B each time line 150 is executed, pressing key 8 increments it.

Recipes 1K

The entire membership of the local ZX81 club is coming for dinner, but your favourite recipe for Haggis Dip is only for three servings. Don't worry ! This program will quickly scale the quantities in any recipe to cater for any number of visiting gourmets. Just enter the number of mouths the recipe was written for, the number you have to feed, then each item, and the scaled quantities will be quickly computed.

The quantity of each item must appear first on each line entered, before the description, and can be entered as a decimal number or as a simple fraction e.g;

2.5 LB BLACK PUDDING
1/4 CUP OF SALT

The results are rounded to one decimal place before printing. To end, enter a null line (just press ENTER (or NEW LINE)).

```
 1Ø PRINT "RECIPE WAS FOR ";
 2Ø INPUT R
 3Ø PRINT R
 4Ø PRINT "NUMBER TO FEED ";
 5Ø INPUT F
 6Ø PRINT F
 7Ø PRINT AT 3,Ø;"ITEMS;"
 8Ø PRINT
1ØØ INPUT I$
11Ø IF I$="" THEN STOP
12Ø FOR C=1 TO LEN I$
13Ø IF I$(C)<>"/" AND I$(C)<"." OR I$(C)>"9" THEN GOTO 15Ø
14Ø NEXT C
15Ø LET V=1
16Ø IF C>1 THEN LET V=F/R*VAL I$( TO C-1)
17Ø PRINT INT (.5+V*1Ø)/1Ø;(I$+" ")(C TO )
18Ø GOTO 1ØØ
```

Of course, you don't have to stick to food. The program can be easily modified to scale any type of component list.

If you've got a ZX printer, why not modify the program to give a permanent record of the new quantities ?

SAM 1K

How many enemy aircraft can you shoot down as they fly across the screen ? Use key "F" to fire your Surface to Air Missile, and "BREAK" if you want to stop before all hundred enemy aircraft have passed.

```
  5 SLOW
 1Ø LET A=Ø
 15 LET G=1ØØ
 2Ø LET H=2Ø
 25 LET I=1
 3Ø FOR B=I TO G
 35 LET C=I+INT (5*RND)
 4Ø LET D=1Ø
 45 PRINT AT D,D;"/"
 5Ø PAUSE G
 55 FOR E=I TO H
 6Ø PRINT AT D,H-D;" "
 65 LET D=D-(I AND (INKEY$ ="F" OR D<>1Ø) AND D)
 7Ø PRINT AT D,H-D;"/" AND D
 75 PRINT AT C,E;" >"
 8Ø IF D<>C OR H-I-D<>E THEN GOTO G
 85 PRINT AT C,E;" *"
 9Ø LET A=A+I
 95 LET E=H
1ØØ NEXT E
1Ø5 PRINT AT H,I;A;" HITS OUT OF ";B;AT C,E;"  ";AT D,H-D;"  "
11Ø NEXT B
```

Note the extensive use of the variables G,H and I in place of numeric constants to reduce the program storage requirements. For example, line 55 takes only 11 bytes instead of the 25 bytes which would be taken by the equivalent;

```
55 FOR E=1 TO 2Ø
```

We could have saved even more by, for example, writing lines 10 to 25 as;

```
1Ø LET I=PI/PI
15 LET A=I-I
2Ø LET H=CODE "="
25 LET G=H*CODE "■"
```

But the program works as it stands, so why complicate things ?

Also of interest is line 65, which decrements D each time it is executed, but only down to zero, and only after key F has been pressed.

Cambridge Crypto 1K

This program is essential for spies from Cambridge, Omsk, or any large multinational as it can translate any message into an almost unbreakable code. To break the code, an enemy would have to know the key used for the particular message, as well as the algorithm used by the ZX81 to generate the Random numbers.

```
 10 PRINT "ENTER;"
 20 PRINT "  E TO ENCODE, D TO DECODE;"
 30 INPUT E$
 40 IF E$<>"E" AND E$<>"D" THEN GOTO 30
 50 PRINT E$
 60 PRINT "  KEY (1-65535)"
 70 INPUT K
 80 IF K>65535 THEN GOTO 70
 90 RAND K
100 CLS
110 PRINT "ENTER MESSAGE"
120 INPUT I$
130 PRINT I$
140 FOR A=1 TO LEN I$
150 LET C=CODE I$(A)
160 IF C<12 OR C>63 THEN GOTO 210
170 LET X=INT (52*RND)
180 IF E$="E" THEN LET X=-X
190 LET C=C+X
200 LET C=C+(52 AND C<12)-(52 AND C>63)
210 PRINT CHR$ C;
220 NEXT A
```

The key is used to set the start of the ZX81's random number sequence in line 90. Lines 150-210 then translate each character of the message except for spaces, graphic characters and ZX81 command words. Line 170 generates a different offset for each character in the message.

CR?S??ORD 1K

Are you a crossword addict ? Or are you trying to think of a name for your latest piece of software ? Then this program will help you. Enter a word (or mnemonic) with the doubtful letters represented by question marks '?', and the program will display a list of 'words', by replacing the question marks with randomly generated characters. When the screen is full, the program will stop with the report 5/70. Enter CONT for more variations.

But be careful who you allow to use this program.
Although egotistic children will enjoy simply seeing variations

on their name, others have been known to use it to 'accidentally' display rude words !

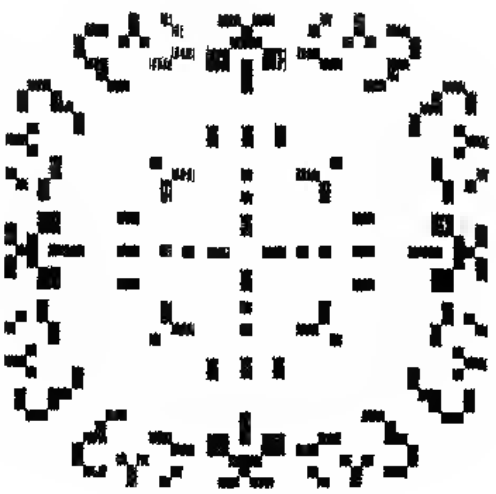
```
10 INPUT A$
20 FOR C=1 TO LEN A$
30 LET B$=A$(C)
40 IF B$<>"?" THEN GOTO 70
50 LET B$=CHR$ (38+25*RND)
60 IF RND<.3 THEN LET B$="AEEIOU"(1+5*RND )
70 PRINT B$;
80 NEXT C
90 GOTO 20
```

Line 60 allows - in a rather crude way - for the fact that vowels occur frequently in English words. Try improving the program so that it more accurately mimics the frequency with which individual letters occur. Alternatively (and this is more difficult than it may seem at first), re-write it so that it generates the missing letters in alphabetic order, rather than at random.

Starburst 1K

This program draws an endless sequence of symmetrical patterns, pausing for applause after each one.

```
10 LET A=CODE "+"
20 LET B=NOT A
30 LET C=B
40 FOR D=C TO A+A*PI*RND
50 LET E=PI*PI*RND
60 LET B=B+E*RND
70 LET C=C+E*RND
80 LET B=B AND B<=A
90 LET C=C AND C<=A

100 PLOT A+B,A+C
110 PLOT A+B,A-C
120 PLOT A-B,A+C
130 PLOT A-B,A-C
140 PLOT A+C,A+B
150 PLOT A+C,A-B
160 PLOT A-C,A+B
170 PLOT A-C,A-B
180 NEXT D
190 PAUSE CODE "■"

200 CLS
210 RUN
```



RAMTEST

Ever had the feeling that your RAM was letting you down ? If so then this program may help. It does a quite thorough check of all the RAM fitted to your system except for that being used by the program, by POKEing random numbers into all of the locations to be tested and then PEEKing to see if they are all still correct. Having gone through the memory once in this fashion, it repeats the test with a different set of random numbers. There are some types of fault that - theoretically - this program won't detect, but they are very rare.

As listed the program will run for ever or until it finds an error - whichever is the sooner. If you omit line 14 then it will only make one 'pass', taking between 30 seconds (1K RAM) and 12 minutes (16K).

The listing below is for a ZX81 with 1K of RAM. Add 1024 to the second value (17351) in lines 7 & 11 for each additional 1K of RAM you have fitted. Also, the first value (16762) in lines 7 & 11 should be changed to 17530 if you have more than 3½K of RAM alltogether. Thus if you have 16K, lines 7 and 11 should read;

```
FOR C=VAL "17530" TO VAL "32711"
```

```
 1 FAST
 2 CLS
 3 LET A=VAL "256"
 4 RAND
 5 LET B=A*RND
 6 RAND B
 7 FOR C=VAL "16762" TO VAL "17351"
 8 POKE C,INT (A*RND)
 9 NEXT C
10 RAND B
11 FOR C=VAL "16762" TO VAL "17351"
12 IF PEEK C<>INT (A*RND) THEN STOP
13 NEXT C
14 RUN
```

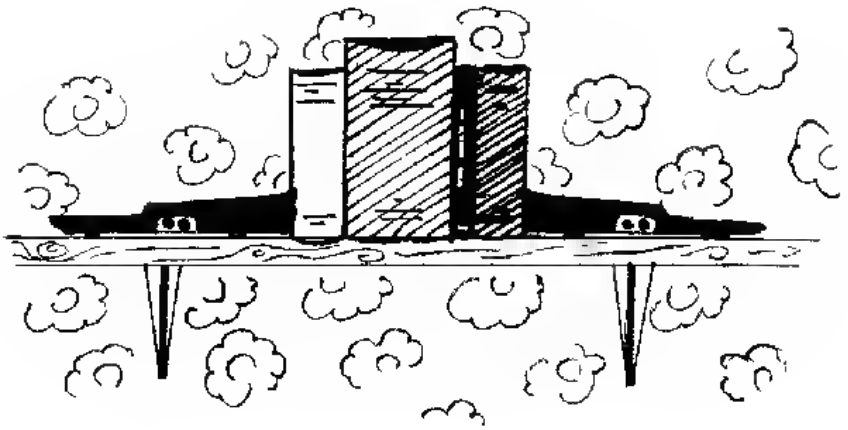
ROMTEST

This program - which takes about a minute to run - checks the contents of the ZX81's ROM for wrong bits.

The old 8K ROM (which insists that SQR .25 is 1.359) should give the answer 854885. The later ROM should give 855106.

```
10 FAST
20 LET A=0
30 FOR B=0 TO 8191
40 LET A=A+PEEK B
50 NEXT B
60 PRINT A
```

Chapter 3



Applications

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61 Bank

Application Notes

It seems that most of the software written for the ZX81 is for games of one form or another. This isn't necessarily a bad thing, writing games programs is an enjoyable way of learning to program a computer and the simple rules and structure of most games means that the program shouldn't be too complicated and so you stand a fair chance of getting it to run . And - after all - games programs are fun to run ! But let us not forget that the ZX81 is more powerful in many ways than the first generation of business computers, and can do many useful jobs in a business or engineering enviroment. And it is not limited to traditional calculating and accounting applications; if fitted with a suitable I/O port is makes an ideal controller for laboratory use in all sciences.

Some examples of such 'useful' programs are given in this chapter - and the reader may find an application for them as they stand, or he may want to tailor them to his specific needs. First, however, it is worthwhile reviewing the strengths and the weaknesses of the ZX81 for 'real' applications.

MATHEMATICAL CAPABILITIES

These are generally very good, notably the ZX81 has a full set of trigonometrical functions, although it doesn't allow the user to define his own functions and there are no matrix arithmetic instructions.

CHARACTER HANDLING

The ZX81 can manipulate characters and strings as least as well as any other computer.

DISPLAY

Most 'proper' computer terminals can display 80 or more characters per line. The ZX81's limit of 32 characters per line is obviously a disadvantage but not a serious one except for word processing applications.

KEYBOARD

No one can pretend that the ZX81 keyboard is ergonomically suited to continuous use ! If you are going to use the machine a lot it is worth buying one of the full sized add-on keyboards now available for the ZX81.

LANGUAGE

BASIC is not an ideal language for large and/or complex programs. It is all too easy to write a program in BASIC that is almost incomprehensible - even to the author - and if you can't understand your program how can you be sure that it will *always* work ?

SECURITY

In this imperfect world, there is always a chance that your program or data can get corrupted while in the computer's memory or while being transferred to and from tape. Large computers have special circuitry to detect errors occuring in the machine itself, and even most microcomputers check to see that the data read from tape is error-free. Unfortunately, the ZX81 does neither of these things and so you cannot really use it for serious accountancy work unless additional routines are included within the program to check data and the program itself for validity as often as required.

SPEED

Reasonable. Not in the Cray supercomputer class, but adequate for most applications.

RANDOM ACCESS MEMORY

With the 16K RAM pack, and allowing for the average size of program, you are left with enough room for about 10000 characters or 2000 floating point numbers. In practical terms, this is equal to about 125 names and addresses. 48K RAM packs are now available which can give you space for over 40000 characters (500 names and addresses).

BULK MEMORY

The most serious disadvantage of the ZX81 for many business applications is that no disc drives are available ; at least not at the time of writing. Most commercial data processing consists of extracting or altering just a small part of a large data file, and the disc drive is ideally for suited for this.

With the ZX81, however, using a domestic cassette recorder limits you to handling data files no longer than can fit into RAM. Although you could, theoretically, break a large file up into RAM sized chunks and deal with each part separately, the difficulties of having to keep starting, stopping and rewinding the recorder, as well as changing tapes, and also the long access time (it takes about 7 minutes to load or save a 16K file, once you have located it on the tape), really make it impracticable except perhaps in very special circumstances.

Overall then, it seems that the ZX81 is best suited to applications which need to input or output only a small amount of data at a time, and which do not use data files larger than about 2000 numbers or 10000 characters. Also, the programmer may need to take special precautions to safeguard against corruption of the program or the stored data. Otherwise, the only limits to using the ZX81 are your imagination and the number of hours in a day !

Std. Dev. 1K

This is an example of the kind of routine calculation work that the ZX81 really likes.

Engineers and statisticians often like to work out the mean and the standard deviation from that mean of a set of sample results. This program will do the calculations, on a set of up to about 20 numbers if you have only 1K RAM, or on a much larger set if you have more RAM fitted.

```
 10 LET B=0
 20 LET D=B
 30 PRINT AT 21,B;"NUMBER OF SAMPLES = ";
 40 INPUT N
 50 PRINT N
 60 DIM A(N)
100 FOR C=1 TO N
110 SCROLL
120 PRINT "SAMPLE ";C;" = ";
130 INPUT A(C)
140 PRINT A(C)
150 LET B=B+A(C)
160 NEXT C
170 SCROLL
180 LET B=B/N
190 PRINT "MEAN = ";B
200 FOR C=1 TO N
210 LET D=D+(A(C)-B)*(A(C)-B)
220 NEXT C
230 SCROLL
240 PRINT "STD DEV = ";SQR (D/N)
```

If you find the program useful, why not modify it to give a permanent record on the ZX printer ?

Ladder Analysis

Based on an Apple II program by S.J.Newett

This program illustrates how the ZX81 can be used for engineering applications which - only a few years ago - would have needed an expensive minicomputer system. If you are already using a mini or a time-sharing system for engineering calculations, try converting some of your favourite programs to run on the ZX81. I bet you'll be suprised at how well this 'toy' performs !

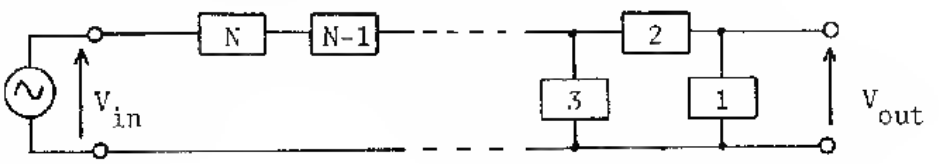
It calculates the gain (or loss), input impedance and output impedance over any range of frequencies for a passive ladder network of up to 10 series or parallel (shunt) branches.

Each parallel branch is a series R L C combination, but if any component is given the value zero then it is treated as a short-circuit. For example, if a parallel branch of the circuit you wanted to analyse was just an inductance, then you would enter the R and C values for that branch as zero. Similarly, series branches are treated as parallel R L C circuits, but any component given the value zero is assumed to be omitted.

Series and parallel branches may be intermixed freely, and are numbered in order starting at the output end of the network.

The program assumes that the driving source is a zero impedance voltage generator, and that the output of the network is connected to an infinite impedance voltage detector. The actual source and load impedances should be included within your model.

When you have entered the component values for all branches in your network, and the frequency range of interest, the program will display in succession the branch values, network gain, input impedance, and output impedance. Each screen full of results ends with a report 9 /.. , inviting you to enter CONT to view the next screen, COPY to get a print-out if you have a ZX printer connected, or STOP if you've had enough.



Generalised N-branch Ladder Network

Generalised 'Series' branch.

Generalised 'Parallel' branch.

Several 2-character variable names have been used in this program, but note that PI and LN are ZX81 functions, not variables.

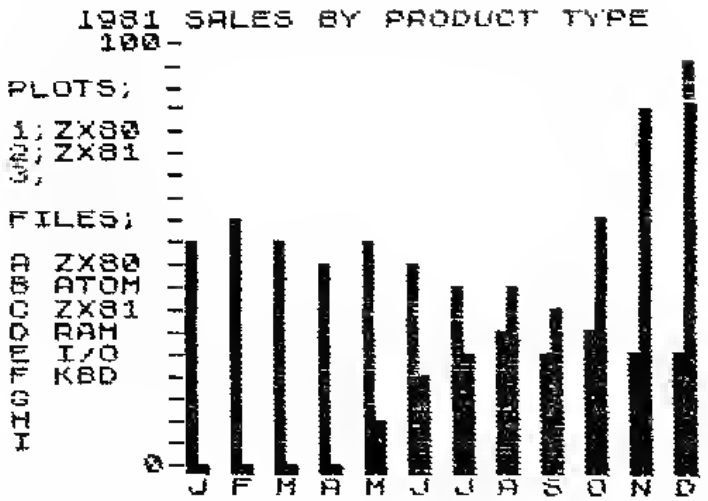
```
100 REM *** LADDER ANALYSIS ***
110 FAST
120 GOSUB 9000
130 GOSUB 8000
140 IF I=1 THEN GOTO 230
150 GOSUB 2000
160 GOSUB 7000
170 GOSUB 6000
180 CLS
190 PRINT "MORE FREQUENCIES (Y/N) ?"
200 INPUT K$
210 IF K$="Y" THEN GOTO 160
220 CLS
230 STOP
240 RUN

1000 REM MULT T() BY QUADRATIC X
1010 FOR I=M(X)+1 TO 1 STEP -1
1020 IF X2<>0 THEN LET T(X,I+2)=T(X,I+2)+T(X,I)*X2
1030 IF X1<>0 THEN LET T(X,I+1)=T(X,I+1)+T(X,I)*X1
1040 LET T(X,I)=T(X,I)*X0
1050 NEXT I
1060 IF X2<>0 THEN LET M(X)=M(X)+2
1070 IF X2<>0 THEN RETURN
1080 IF X1<>0 THEN LET M(X)=M(X)+1
1090 RETURN

1200 REM MULT T() BY QUAD S, ADD RESULT TO T()
1210 FOR I=1 TO M(Y)+1
1220 LET T(X,I+S)=T(X,I+S)+T(Y,I)
1230 NEXT I
1240 IF M(Y)+S>M(X) THEN LET M(X)=M(Y)+S
1250 RETURN

1400 REM MAKE ANGLE -180 TO 180
1410 LET AN=AN-360*INT ((AN+180)/360)
1420 RETURN

2000 REM CALCULATE MATRICES
2010 FOR B=1 TO I-1
2020 LET X0=0
2030 LET X1=0
2040 LET X2=0
2050 IF E(B)=1 THEN GOTO 2100
2060 IF C(B)>0 THEN LET X2=C(B)
2070 IF R(B)>0 THEN LET X1=1/R(B)
2080 IF L(B)>0 THEN LET X0=1/L(B)
2090 GOTO 2130
2100 IF C(B)>0 THEN LET X0=1/C(B)
2110 IF R(B)>0 THEN LET X1=R(B)
```

```
2120 IF L(B)>0 THEN LET X2=L(B)
2130 LET S=1
2140 IF X0>0 THEN GOTO 2190
2150 LET X0=X1
2160 LET X1=X2
2170 LET X2=0
2180 LET S=0
2190 FOR C=1 TO 2
2200 LET X=C+2*E(B)
2210 LET Y=C+2*(1-E(B))
2220 GOSUB 1000
2230 GOSUB 1200
2240 LET X=Y
2250 GOSUB 1000
2260 NEXT C
2270 LET X=5
2280 GOSUB 1000
2290 NEXT B
2300 LET U=0
2310 FOR I=1 TO 5
2320 IF M(I)>U THEN LET U=M(I)'
2330 NEXT I
2340 RETURN

3000 REM SAFE DIVISION
3010 IF ABS DD<1E-30 THEN LET DD=1E-30
3020 IF ABS DV<1E-30 THEN LET DV=1E-30
3030 IF 1E-30*ABS DD>ABS DV THEN GOTO 3060
3040 LET QU=DD/DV
3050 RETURN
3060 LET QU=1E30*SGN DD/SGN DV
3070 RETURN

6000 REM DISPLAY RESULTS
6010 FOR I=2 TO 6 STEP 2
6020 CLS
6030 PRINT "FREQ      ";
6040 IF I=2 THEN PRINT "GAIN (DB)";
6050 IF I=4 THEN PRINT "I/P OHMS ";
6060 IF I=6 THEN PRINT "O/P OHMS ";
6070 PRINT "      ANGLE"
6080 FOR L=1 TO 20
6090 PRINT AT L+1,0;Z(L,1);TAB 9;Z(L,I);TAB 25;INT (10*Z(L,I+1)
     +.5)/10
6100 NEXT L
6110 STOP
6120 NEXT I
6130 RETURN

7000 REM FREQUENCY ANALYSIS
7010 GOSUB 8500
7020 LET NF=1
7030 LET F=F1+(NF-1)*F2
7040 LET W=2*PI*F
7050 LET V=1
```

```
7060 FOR J=1 TO 5
7070 LET K(J,1)=0
7080 LET K(J,2)=0
7090 NEXT J
7100 LET AI=-1
7110 FOR I=0 TO U
7120 LET AI=-AI
7130 LET BI=1+(AI<0)
7140 FOR J=1 TO 5
7150 LET K(J,BI)=K(J,BI)+V*T(J,I+1)
7160 NEXT J
7170 LET V=AI*V*W
7180 NEXT I
7190 FOR J=1 TO 5
7200 LET P(J,1)=SQR (K(J,1)*K(J,1)+K(J,2)*K(J,2))
7210 LET DD=K(J,2)
7220 LET DV=K(J,1)
7230 GOSUB 3000
7240 LET P(J,2)=(180/PI)*ATN QU
7250 IF K(J,1)<0 THEN LET P(J,2)=P(J,2)+180
7260 NEXT J
7400 LET Z(NF,1)=F
7410 LET DD=P(5,1)
7420 LET DV=P(1,1)
7430 GOSUB 3000
7440 LET Z(NF,2)=20*.43429*LN QU
7450 LET AN=P(5,2)-P(1,2)
7460 GOSUB 1400
7470 LET Z(NF,3)=AN
7480 LET DD=P(1,1)
7490 LET DV=P(3,1)
7500 GOSUB 3000
7510 LET Z(NF,4)=QU
7520 LET AN=P(1,2)-P(3,2)
7530 GOSUB 1400
7540 LET Z(NF,5)=AN
7550 LET DD=P(2,1)
7560 LET DV=P(1,1)
7570 GOSUB 3000
7580 LET Z(NF,6)=QU
7590 LET AN=P(2,2)-P(1,2)
7600 GOSUB 1400
7610 LET Z(NF,7)=AN
7620 IF NF=20 THEN RETURN
7630 LET NF=NF+1
7640 GOTO 7030

8000 REM INPUT BRANCHES
8010 FOR I=1 TO 10
8020 CLS
8030 PRINT "BRANCH ";I;"     TYPE"
8040 PRINT AT 2,5;"S - FOR SERIES BRANCH"
8050 PRINT TAB 5;"P - FOR PARALLEL"
```

```
8060 PRINT TAB 5;"E - TO END"
8070 INPUT K$
8080 IF K$="E" THEN GOTO 8300
8090 IF K$<>"S" AND K$<>"P" THEN GOTO 8070
8100 PRINT AT 0,18;K$
8110 LET E(I)=1 AND K$="P"
8120 PRINT AT 6,1;"INDUCTANCE (HENRIES) ="
8130 INPUT L(I)
8140 PRINT AT 6,25;L(I)
8150 PRINT AT 7,1;"RESISTANCE (OHMS)    ="
8160 INPUT R(I)
8170 PRINT AT 7,25;R(I)
8180 PRINT AT 8,1;"CAPACITANCE(FARADS)  ="
8190 INPUT C(I)
8200 NEXT I
8300 IF I=1 THEN RETURN
8310 CLS
8320 PRINT "BR    IND      RES     CAP"
8330 FOR L=1 TO I-1
8340 PRINT AT L+2,0;L;TAB 3;("S " AND E(L)=0);("P " AND E(L)<>0
     );L(L);TAB 14;R(L);TAB 23;C(L)
8350 NEXT L
8360 STOP
8370 RETURN

8500 REM GET FREQ RANGE
8510 CLS
8520 PRINT "LOWFST FREQ (HZ)  ?"
8530 INPUT F1
8540 PRINT AT 0,17;F1
8550 PRINT AT 2,0;"FREQ STEP (HZ)   ?"
8560 INPUT F2
8570 RETURN

9000 REM INITIALISE
9010 DIM L(10)
9020 DIM R(10)
9030 DIM C(10)
9040 DIM E(10)
9050 DIM T(5,20)
9060 DIM M(5)
9070 DIM K(5,2)
9080 DIM P(5,2)
9090 DIM Z(20,7)
9100 LET T(1,1)=1
9110 LET T(4,1)=1
9120 LET T(5,1)=1
9130 RETURN
```

G.P.G.P.



This General Purpose Graph Plotter can be used as a 'live' aid during presentations of business figures, or for the preparation of printed reports.

It can hold up to 9 files, each containing values for each of the 12 months of a year, and can plot up to 3 files on the screen in bar chart form at any time. A useful feature is that any of the three bar charts displayed can be replaced by another one on demand while the other two remain un-affected. Different sets of files can be saved on tape under different names.

Whenever the program is waiting for instructions it will display the familiar L cursor at the bottom left of the screen. You can then enter;

EM	to change the maximum value of the graphs. This changes the scaling factor so the graphs have to be re-plotted after using this command.
ET	to change the title shown at the top of the display.
C	to clear any plotted graphs from the screen.
S	to save the program with the current data files to tape, using the title shown at the top of the screen as the name.
EA to EI	to enter data into one of the nine data files A to I, or to change data already entered.

To plot a graph from one of the data files, enter the number 1, 2 or 3 according to whether you want the bars plotted in the left, middle or right position, followed by a letter A-I specifying which file you want plotted. For example, to plot the contents of file B on the left side, enter '1B'.

```
  1 REM G.P.G.P.
  2 GOTO 9000

100 REM BAR PLOT
110 FOR C=2 TO B
120 PLOT D,C
130 NEXT C
140 IF C>41 THEN RETURN
150 FOR C=C TO 41
160 UNPLOT D,C
170 NEXT C
180 RETURN

1000 REM MAIN ROUTINE
1010 INPUT A$
1020 IF A$="C" THEN GOTO 2000
1030 IF A$="S" THEN GOTO 3000
1040 IF LEN A$<>2 THEN GOTO 1010
1050 IF A$(1)="E" THEN GOTO 5000
1060 IF A$(1)>"0" AND A$(1)<"4" THEN GOTO 6000
1070 GOTO 1010

2000 REM CLEAR SCREEN
2010 FAST
2020 CLS
2030 PRINT T$;AT 1,0;M$;AT 3,0;"PLOTS;";AT 20,6;"0"
2040 FOR A=1 TO 20
2050 PRINT AT A,7;"-";Z$
2060 NEXT A
2070 PRINT TAB 8;L$
2080 FOR A=1 TO 3
2090 PRINT AT 4+A,0;A;";"
2100 NEXT A
2110 GOSUB 4000
2120 SLOW
2130 GOTO 1000

3000 REM SAVE
3010 LET B$=T$
3020 IF B$(1)<>" " OR LEN B$=1 THEN GOTO 3050
3030 LET B$=B$(2 TO )
3040 GOTO 3020
3050 IF B$(LEN B$)<>" " OR LEN B$=1 THEN GOTO 3080
3060 LET B$=B$( TO LEN B$-1)
3070 GOTO 3050
3080 IE B$=" " THEN LET B$="GRAPH"
3090 PRINT AT 21,0;"START RECORDER THEN PRESS KEY Y"
3100 IF INKEY$<>"Y" THEN GOTO 3100
3110 SAVE B$
3120 PRINT AT 21,0;Z$,AT 21,8;L$
3130 GOTO 1000
```

```
4000 REM NAME LIST
4010 PRINT AT 9,0;"FILES"
4020 FOR A=1 TO 9
4030 PRINT AT A+10,0;CHR$ (37+A);" ";N$(A)
4040 NEXT A
4050 RETURN

4500 REM DELETE NAME LIST
4510 FOR A=9 TO 19
4520 PRINT AT A,0;S$
4530 NEXT A
4540 RETURN

5000 REM EDIT
5010 IF A$(2)<"A" OR (A$(2)>"I" AND A$(2)<>"M" AND
     A$(2)<>"T") THEN GOTO 1000
5020 GOSUB 4500
5040 IF A$(2)="M" THEN GOTO 5300
5050 IF A$(2)="T" THEN GOTO 5400
5100 PRINT AT 12,0;"GRAPH";A$(2)
5110 LET G=CODE A$(2)-37
5120 PRINT AT 14,0;"NAME ?"
5130 INPUT N$(G)
5140 PRINT AT 14,0;N$(G),AT 16,0;"DATA"
5150 PRINT "FOR";AT 18,0;"MONTH:"
5160 FOR A=1 TO 12
5170 PRINT AT 19,0;A;" ?"
5180 INPUT D(G,A)
5190 NEXT A
5200 GOSUB 4000
5210 GOTO 1000

5300 PRINT AT 18,0;"NEW MAX";AT 19,0;"VALUE ?"
5310 INPUT M
5320 LET B$=STR$ M
5330 LET M$=Z$
5340 LET M$(8-LEN B$ TO )=B$
5350 GOTO 2000

5400 PRINT AT 18,0;"NEW";AT 19,0;"TITLE ?"
5410 INPUT B$
5420 LET T$=Z$
5430 IF LEN B$>32 THEN LET B$=B$( TO 32)
5440 LET T$((33-LEN B$)/2 TO )=B$
5450 PRINT AT 0,0;T$
5460 GOTO 5200

6000 REM PLOT
6010 IF A$(2)<"A" OR A$(2)>"I" THEN GOTO 1000
6020 LET G=CODE A$(2)-37
6030 LET P=CODE A$(1)-CODE "0"
6040 PRINT AT 4+P,2;N$(G)
6050 FOR M=1 TO 12
6060 LET B=2+INT (D(G,M)*40/VAL M$+.5)
```

```
6070 IF B>41 THEN LET B=41
6080 LET D=P+11+4*M
6090 GOSUB 100
6100 NEXT M
6110 GOTO 1000

9000 REM INITIALISE
9010 DIM T$(32)
9020 DIM M$(7)
9030 DIM N$(9,5)
9040 DIM D(9,12)
9050 DIM Z$(24)
9060 DIM S$(7)
9080 LET M$(7)="1"
9080 LET L$="J F M A M J J A S O N D"
9090 GOTO 2000
```

Items that may be worthy of note in the program are the routines to centralise the title on the screen (5420- 5450), to right justify the max value (5320-5340) and to strip leading and trailing spaces from T$ so that it can be used for the name when saving the program and data to tape (3010-3070). The heart of the plotting routine is placed at the beginning of the program listing (lines 100-180) for speed.

If your year starts in a month other than January, change L$ (line 9080) accordingly.

Bank

```
                    STATEMENT
1/1/82
 I.B.M.                        £1000.00CR
1/1/82
 SINCLAIR                      £2000.00CR
2/1/82      CHQ/11111
 ME                             £500.00
5/1/82      CHQ/11112
 ELECTRICITY                     £98.50
10/1/82     CHQ/11113
 CLIVE                          £500.00
19/1/82     CHQ/11114
 TELEPHONE                       £35.79

                    BALANCE:  £1935.77

LAST ENTRY:6
ENTER NUMBER TO REVIEW,
OR NEWLINE FOR MENU
```

By J.Durst

This program will keep track of your personal bank account. It holds a file of up to 100 entries, with name, date and amount, and will display a statement of any 7 consecutive entries together with the current balance. Credit entries (payments into the bank account) are marked, as are debit (overdraft) balances.

After entering data, use the 'SV' option to save an updated file to tape. When the file is full, the first 90 entries can be deleted, and the last 10 moved up, to start a new ledger. Dates should be entered as 4 digits e.g. 7th. July as 0707. The year can be changed by altering A$ (line 150).

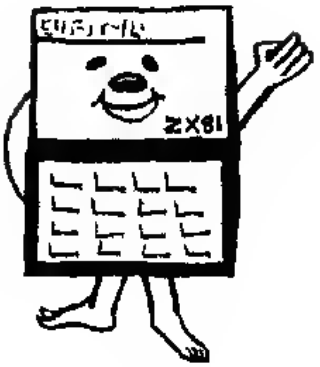
```
 10 LET I=0
 20 LET RESET=0
 30 DIM D$(100,4)
 40 DIM C(100)
 50 DIM N$(100,15)
 60 DIM S(100)

100 LET MENU=380
110 LET DEBIT=530
120 LET CREDIT=830
130 LET STATEMENT=1090
140 LET TOTAL=0
150 LET A$="/82"

200 LET K=0
210 GOTO MENU
220 REM SUBROUTINE PRINT DATE
230 IF D$(J,1)="0" THEN GOTO 250
240 PRINT D$(J,1);
250 PRINT D$(J,2);"/";
260 IF D$(J,3)="0" THEN GOTO 280
270 PRINT D$(J,3);
280 PRINT D$(J,4);A$;
290 RETURN

300 REM SUBROUTINE POUNDS/PENCE
310 PRINT "£":INT ABS S(J):".";
320 LET PENCE=INT (100*ABS S(J)-100*INT ABS S(J)+.5)
330 IF PENCE=0 THEN PRINT "00";
340 IF PENCE=0 THEN RETURN
350 IF PENCE<10 THEN PRINT "0";
360 PRINT PENCE;
370 RETURN

380 REM MENU
390 PRINT AT 3,9;"BANK BALANCE"
400 PRINT AT 5,8;"(ACCOUNT NAME)"
410 PRINT AT 6,13;A$
420 PRINT AT 9,4;"CR - FOR CREDIT ENTRY";AT 11,4;"DB - FOR
    DEBIT ENTRY"
430 IF I<>0 THEN PRINT AT 13,4;"ST - FOR STATEMENT"
440 PRINT AT 15,4;"SV - TO SAVE ON TAPE"
450 IF I=99 THEN PRINT AT 16,0;"*LAST ENTRY BEFORE FILE FULL*"
460 INPUT Y$
470 CLS
480 IF Y$="CR" THEN GOTO CREDIT
490 IF Y$="DB" THEN GOTO DEBIT
500 IF Y$="ST" THEN GOTO STATEMENT
```

```
510 IF Y$="SV" THEN SAVE "BANK"
520 GOTO 380

530 REM DEBIT ENTRY
540 LET I=I+1
550 LET J=1
560 PRINT AT 3,10;"DEBIT ENTRY"

570 REM ENTER DATE
580 PRINT AT 5,4;"DATE: ";
590 INPUT D$(J)
600 GOSUB 220
610 PRINT
620 REM ENTER CHEQUE NO.
630 PRINT AT 7,4;"CHEQUE NUMBER: ";
640 INPUT C(J)
650 PRINT "/";C(J)
660 REM ENTER PAYEE NAME
670 PRINT AT 9,4;"PAYEES NAME: ";
680 INPUT N$(J)
690 PRINT N$(J)
700 REM ENTER AMOUNT
710 PRINT AT 11,4;"AMOUNT: ";
720 INPUT S(J)
730 LET S(J)=-S(J)
740 GOSUB 300
750 PRINT AT 20,0;"NEWLINE - FOR MENU"
760 PRINT AT 21,4;"COR - FOR CORRECTION"
770 INPUT Y$
780 CLS
790 IF Y$="COR" THEN GOTO 560
800 IF I=100 THEN GOTO STATEMENT
810 GOTO MENU

830 REM CREDIT ENTRY
840 LET I=I+1
850 LET J=I
860 PRINT AT 3,9;"CREDIT ENTRY"
870 REM ENTER DATE
880 PRINT AT 5,4;"DATE: ";
890 INPUT D$(J)
900 GOSUB 220
910 PRINT
920 REM ENTER NAME
930 PRINT AT 7,4;"PAYERS NAME: ";
940 INPUT N$(J)
950 PRINT N$(J)
960 REM ENTER AMOUNT
970 PRINT AT 9,4;"AMOUNT: ";
980 INPUT S(J)
990 GOSUB 300

1000 PRINT AT 20,0;"NEWLINE - FOR MENU"
1010 PRINT AT 21,4;"COR - TO CORRECT ENTRY"
```

```
1020 INPUT Y$
1030 CLS
1040 IF Y$="COR" THEN GOTO 860
1050 IF I=100 THEN GOTO STATEMENT
1060 GOTO MENU

1090 REM STATEMENT
1100 FAST
1110 CLS
1120 PRINT AT 0,10;"STATEMENT"
1130 PRINT
1140 FOR K=100 TO 1 STEP -1
1150 IF S(K)=0 THEN NEXT K
1160 LET Q=K
1170 FOR J=Q-6 TO Q
1180 IF J<1 THEN NEXT J
1200 GOSUB 220
1210 IF C(J)=0 THEN PRINT
1220 IF C(J)=0 THEN GOTO 1240
1230 PRINT TAB 10;"CHQ/";C(J)
1240 PRINT " ";N$(J);TAB (24-LEN STR$ INT ABS S(J));
1250 GOSUB 300
1260 IF S(J)>0 THEN PRINT "CR";
1270 PRINT
1300 NEXT J
1310 REM GET TOTAL
1320 LET TOTAL=RESET
1330 FOR T=1 TO K
1340 LET TOTAL=TOTAL+S(T)
1350 NEXT T

1360 LET PENCE=INT (100*(ABS TOTAL-ABS INT TOTAL)+.5)
1370 LET T$=STR$ ABS INT TOTAL
1380 PRINT AT 17,11;"BALANCE: £";T$;".";
1390 GOSUB 330
1400 IF TOTAL<0 THEN PRINT "*OD"
1410 PRINT AT 19,0;"LAST ENTRY:";Q
1420 IF I=99 THEN PRINT AT 19,0;"FINAL ENTRY BEFORE FILE
     FULL"
1430 PRINT AT 20,0;"ENTER NUMBER TO REVIEW,"
1440 PRINT AT 21,0;"OR NEWLINE FOR MENU"
1450 IF I=100 THEN PRINT AT 21,0;"FILE FULL; NEWLINE TO
     RE-NUMBER"
1460 SLOW
1470 INPUT Y$
1480 CLS
1490 IF Y$="" AND I=100 THEN GOTO 1540

1500 IF CODE Y$<29 OR CODE Y$>37 THEN GOTO MENU
1510 IF VAL Y$>=1 AND VAL Y$<101 THEN LET Q=VAL Y$
1520 IF VAL Y$>=1 AND VAL Y$<101 THEN GOTO 1170
1530 CLS
1535 GOTO MENU
```

```
1540 PRINT "FILE IS NOW FULL."
1550 PRINT AT 4,0;"ST - FOR CURRENT STATEMENT"
1560 PRINT AT 6,0;"NEWLINE WILL ERASE ALL BUT LAST 10
     ENTRIES"
1570 INPUT Y$
1580 IF Y$<>"" THEN GOTO MENU
1590 FAST
1600 LET T2=0
1610 FOR J=91 TO 100
1620 LET D$(J-90,4)=D$(J,4)
1630 LET C(J-90)=C(J)
1640 LET N$(J-90,15)=N$(J,15)
1650 LET S(J-90)=S(J)
1660 LET T2=T2+S(J)
1670 NEXT J
1680 LET RESET=TOTAL-T2
1690 FOR J=11 TO 100
1700 LET D$(J,4)=""
1710 LET C(J)=0
1720 LET N$(J,15)=""
1730 LET S(J)=0
1740 NEXT J
1750 LET I=0
1760 CLS
1770 SLOW
1780 GOTO STATEMENT
```

Chapter 4



Machine Language

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Binary & Hexadecimal

Why do people write Machine Language programs in Hexadecimal ? Why do computers work in Binary ? What is a Byte ?

If you already know the answers please feel free to skip this section. If not, then read on !

If you take a look at the ZX81 rear connector diagram shown in chapter 26 of the Sinclair ZX81 BASIC Manual, you should see that eight of the connections are labelled DØ - - D7. These form the computer's 'data bus', and carry all of the data being manipulated, and all of the instructions which say how to manipulate that data, between the Z80 processor and the ROM and RAM memories. When you plug the ZX81 printer onto this connector, it also uses the data bus lines to communicate with the processor.

When any device (RAM, Z80 etc,) is reading data from the data bus it looks for one of two voltage levels on each of the data lines DØ - D7;

- A 'low' level, which is anything below about 0.8 volts.
- A 'high' level, anything above about 2 volts.

And when a device is putting data onto the bus, it feeds each of the data lines with;

- A 'low' level of between 0 and 0.4V.

or - A 'high' level of between 2.4 and 5V.

Comparing the voltage levels sent onto the bus with those accepted by a device which is reading data from the bus lines, you can see that there is a reasonable margin and small amounts of electrical 'noise' which may get added onto the signal are ignored. This is good for the security of your data and one reason why digital computers have proved so popular. The other reason is that it is relatively easy - and hence cheap - to manufacture integrated circuits to meet the wide tolerances on the input threshold and output voltage levels.

The result of all this is that we have a data bus consisting of eight wires each carrying one of two voltage levels. If we represent the 'high' voltage level by the number '1', and the 'low' level by 'Ø', then we can write the combined signal on the data bus at any time as a string of eight '1's or 'Ø's e.g;

1Ø1ØØ11Ø

Now when we write down a number in our 'natural' ten-fingered decimal system, we use the symbols 0 to 9, and write the individual digits of a number in order so that - working from the right hand digit towards the left hand digit - each digit is assumed to be multiplied by the next power of 10. Thus

```
            1328

means         8 * 1
            + 2 * 10
            + 3 * 100
            + 1 * 1000
```

The eight signals on the data bus are treated similarly,except that as each data bus line, or digit of the number written, can only be one of two symbols (Ø or 1), then each digit in the number is assumed to be multiplied by the next power of 2.Thus;

```
            1Ø1ØØ11Ø

means         0 * 1
            + 1 * 2
            + 1 * 4
            + 0 * 8
            + 0 * 16
            + 1 * 32
            + 0 * 64
            + 1 * 128
```

Since we are working with 2 symbols, this is known as a 'binary' numbering system, as opposed to our 'natural' decimal (or denary) system which uses 10 symbols. Each digit in a binary number is known as a 'bit'.

Referring back to the data bus, DØ corresponds to the rightmost (least significant) binary digit, and D7 to the leftmost (most significant) one. You wil - of course - have noticed that the number of each data line corresponds to the relevant power of 2;

```
D7 - - - - D2 D1 DØ
|          |  |  └──2 to the power 0 = 1
|          |  └─────2 to the power 1 = 2
|          └────────2 to the power 2 = 4
|                   -----
└── - - - ──────────2 to the power 7 = 128
```

Which is convenient and - presumably - why the data lines are numbered Ø to 7 rather than 1 to 8.

The combined eight bits are known as a 'byte' - perhaps because the Z8o processor 'gobbles up' the data in these 8-bit chunks. For the record, a group of 4 bits is sometimes known as a 'nibble'.

If you care to work it out, you will find that a byte can represent any number in the range zero (ØØØØØØØØ) to 255 (11111111). Numbers in this range are used by the ZX81 to represent alphanumeric and graphics characters, keywords, and various other tokens as listed in Appendix A of the Sinclair ZX81 BASIC Manual.

Also on the ZX81's rear connector are sixteen lines labelled AØ to A15. These are the computer's 'address' lines, which again carry binary signals. They are driven by the Z80 processor, and the number they carry specifies which memory byte the processor

wants to read from or write to.The first eight lines AØ to A7 each correspond to the first eight powers of 2 - as with the data lines. The other eight address lines correspond to increasingly higher powers of 2;

```
A15 - - - - - - - A8
|                 └──── 2 to the power 8 = 256
|                 ------
└─ - - - - - - - - - - 2 to the power 15 = 32768
```

In this way the binary signals on the 16-bit address bus can represent numbers from Ø to 65535, giving the ZX81 a theoretical capability of addressing up to 65536 memory bytes, or (using the computer enthusiast's shorthand 'K' meaning 1024) 64K bytes.

Hopefully it is now clear that when you are dealing with the signals on the ZX81's data and address busses you are really dealing with 8 or 16 bit binary numbers. Since a Machine Language program is concerned almost entirely with these 8 and 16 bit numbers, and often with the state of individual bits within a data byte, it makes sense for us to write such programs in a form which is close to the way the machine actually handles data and addresses. For example, in writing a data byte as;

1ØØØØØ1

it is much easier to see whether - say - bit 3 is a Ø or a 1 than if we had written the equivalent decimal number 129.

But, binary numbers are not all that easy for humans to handle. For example, try to remember the 16-bit address;

11ØØ1Ø11ØØ111ØØØ

for five minutes. What is needed is some half-way house, which allows us to handle the numbers easily but without decimal's drawback of having no easy correspondence with the individual bits in the original binary number. This is where Hexadecimal makes its triumphant appearance !

The Hexadecimal numbering system works to the base 16 - rather than the base 10 used by decimal and base 2 by binary.
It therefore requires 16 different symbols to represent the digits, and for convenience the numbers Ø to 9 plus the letters A to F are used. Because there are sixteen possible symbols, each hexadecimal digit is exactly equivalent to four binary bits;

Binary	Hexadecimal	Decimal	Binary	Hexadecimal	Decimal
ØØØØ	Ø	Ø	1ØØØ	8	8
ØØØ1	1	1	1ØØ1	9	9
ØØ1Ø	2	2	1Ø1Ø	A	1Ø
ØØ11	3	3	1Ø11	B	11
Ø1ØØ	4	4	11ØØ	C	12
Ø1Ø1	5	5	11Ø1	D	13
Ø11Ø	6	6	111Ø	E	14
Ø111	7	7	1111	F	15

Having found a convenient way of representing four binary bits, all that remains is to divide our 8-bit byte or 16-bit address into 4-bit nibbles. Using the example given earlier;

```
11ØØ1Ø11ØØ111ØØØ
  C   B   3   8
```

Now isn't 'CB38' easier to remember than that long string of Ø's and 1's ?

Converting a hexadecimal number to decimal is also fairly easy as - working from right to left - each hexadecimal digit represents a successively higher power of 16. Thus;

```
CB38        8*1          =     8
            3*16         =    48
           11*16*16      =  2816
           12*16*16*16   = 49152
                           52024
```

Floating point binary

The ZX81 stores the values of numbers (variables and constants) in 5-byte binary floating point form.

The first of the five bytes is used to hold the binary 'exponent', the remaining four bytes hold the sign of the number and the 'mantissa'. The overall value of the number is;

'sign' 'mantissa' times 2 to the power 'exponent'

so if the sign was '+', the mantissa '3' and the exponent '4', the value of the number would be;

+ 3 times 2 to the power 4 = 48

In practice the mantissa is always scaled by multiplying or dividing it by powers of 2 , and the exponent adjusted accordly , so that the mantissa is a 32 bit binary fraction in the range .10000---- to .1111111---- (in decimal terms this would be .5 to .9999999--).

Because the left hand (most significant) bit of the mantissa is always a '1', there is no need to actually store it, so the ZX81 puts a 'sign' bit in its place. This is 1 for a negative number, Ø for a positive one.

The value of the exponent byte is offset by -128, so that;

ØØØØØØØØ	represents an exponent of -128
Ø1111111	represents an exponent of -1
1ØØØØØØØ	represents an exponent of Ø
11111111	represents an exponent of 127

A number having the value 'Ø' presents a slight problem, as you can't accurately represent it by a mantissa having a leading '1'. In practice the ZX81 stores the value 'Ø' as five zero bytes, or .5 times 2 to the power 128, but it takes care in arithmetic routines to note that this actually represents zero.

Using USR

The USR function allows us to call a Machine Language routine,and can return a value to the calling BASIC program.

The Sinclair ZX81 BASIC Manual is rather reticent about its use, but perhaps that is to be expected, as USR opens the door to the whole complex and detailed topic of Machine Language programming which is a subject large enough to justify a book in its own right. In fact several have been written, of which possibly the best for the ZX81 owner is 'Mastering Machine Code on your ZX81' by Tony Baker.

Because the subject is so large, we can't explore it fully in a general book like this either. What we can do, however, is to give the 'flavour' of Machine Language, with examples of simple Machine Code routines, so that the reader can see if it is a subject he wishes to study further.

The Z80 Processor

This is the 'brains' of the ZX81, where all the calculations are actually performed. It is connected to the ZX81's ROM and RAM memories, from where it can get instructions and data, and can put results back into the ZX81's RAM. It also has several small internal memories, known as 'registers', which it uses as a 'scratch pad' for holding temporary values. These registers each hold one 8-bit byte, or may be used in pairs to handle 16 bit words.

Although it is a very clever chip, the Z80 processor doesn't itself understand BASIC. What it does understand are programs written in a special language known as 'Z80 Machine Language' and stored in 'Machine Code'.

The ROM chip in the ZX81 contains such a machine language program, known as the 'BASIC Interpreter'. It is by running this program that the Z80 manages to understand and so execute your BASIC program. For each line in the BASIC program, the Z80 may actually have to execute hundreds, or even thousands, of instructions from the Interpreter program, doing things such as working out exactly what your statement means, checking for any errors, and calculating where the variables have been stored, as well as evaluating any string or arithmetic expression you may have used.

Other machine language routines within the ZX81's ROM are used for scanning the keyboard, for LOADing and SAVEing your BASIC program, and for providing the TV display.

USR may be used to call one of these routines within the ROM, or it may call a routine that has been specially written for some particular application and stored in an area of RAM.

Machine Language

Each instruction in Z80 Machine Language consists of one or more 8-bit bytes, which for convenience we usually write in hexadecimal rather than binary form, and comprises an Operation Code possibly followed by data or an address. Thus;

3C

means 'add one to the A register', and;

3E Ø1

means 'load the A register with the value Ø1'.

Since these hexadecimal codes are not all that easy to work with, machine language programs are usually first written in a mnemonic form which is later translated to hexadecimal. The examples shown above would be written in mnemonic form as;

INC A

and LDA Ø1

Programs written in this mnemonic form are often known as 'Assembly Language Programs', and 'Assembler' programs are available that will take a program written in Assembly Language and convert it to hexadecimal and also to the actual binary codes used by the Z80 processor.

When giving a listing of a Machine / Assembly Language program, it is usual to show it in the following format;

- First the address of the memory location in which the first byte of the instruction is to be stored, expressed as four hex digits.
- Then the hexadecimal version of the instruction.
- Any 'label' used, followed by a colon.
- The mnemonic version of the instruction.
- Any comments you may care to put, explaining the routine.

An example, taken from the start of the ZX81's ROM, is;

address	instruction	label	instruction	comment
ØØØØ	D3 FD	RESET:	OUT FD,A	
ØØØ2	Ø1 FF 7F		LD BC, 7FFF	HIGH RAM ADDRESS

The 'labels' are used as convenient pointers to useful parts of the program, for example a later JUMP instruction could be written as;

JP RESET

rather than JP ØØØØ

The Assembler program will then fill in the correct address as it converts the mnemonic code to hex and binary.

In summary, the advantages of machine language routines are;

- They can be very fast, particularly in applications such as altering all or part of the display, searching for a particular sequence of codes in a large area of memory, or repeating a simple operation many many times. All of the best moving graphics games and those such as Chess which involve a lot of computation are written in machine code.

- They often occupy fewer memory bytes than a similar BASIC routine.

- They can be used to control ZX81 features (such as the tape in and out ports) which are not directly accessible from ZX81 BASIC.

But of course there are disadvantages, the main one being the length of time it takes to write and successfully debug a machine language program. If the author's experience is anything to go by it can take between ten and twenty times longer to get a machine language program working than it would have taken for a similar BASIC routine !

Where To Put It

The first problem to arise when you start to write a machine language program is where to put it. The machine code must be stored somewhere in RAM, but must not conflict with ZX81 BASIC's use of memory. There are several alternatives.

REM at first

One way, as suggested in the Sinclair ZX81 BASIC manual, is to make the first line of your program a REM statement, with at least one character after the REM for each byte in your machine code, e.g;

```
1 REM 1234567890
```

which will reserve ten bytes (at locations 16514 to 16523) into which you can POKE the values of the machine code bytes.

The resulting BASIC program may look strange when you LIST it, but it can be SAVEd - complete with the POKEd machine code - and will RUN without any problems except that sometimes the value 118 (hex 76) can confuse the ZX81, as this is the code for NEWLINE. The value 126 (hex 7E) also needs some care as it makes the ZX81 BASIC interpreter skip the next 5 bytes - thinking that they are a floating point binary number. This stops it LISTing these five bytes, and if they include the start of the next line then the program will not run properly.

Once the machine code has been stored, the function USR x should be used to run it, x being the starting address of the machine code routine.

As a very simple example, enter the program;

```
1 REM 1234
2 PRINT USR 16514
```

then, before you RUN it, enter;

```
POKE 16514,1
POKE 16515,Ø
POKE 16516,Ø
POKE 16517,2Ø1
```

RUN should now give the result 'Ø' as the machine code routine was;

```
LD BC , ØØØØ
RET
```

i.e. load the register pair BC with the value Ø , then return to the calling BASIC program. As the function USR always gives the value of the BC register pair as a result, this is printed out.

Instead of laboriously POKEing every value, we can choose the characters typed after the REM to have the correct codes. Since;

```
CODE " " = Ø
CODE "■" = 1
CODE TAN = 2Ø1
```

we could enter the 4-byte machine code routine by simply keying in the line;

1 REM ■ *space space* TAN

noting that the symbol ■ is entered with the aid of the GRAPHICS key, and TAN with the FUNCTION key.

Looking through Appendix A of the Sinclair ZX81 BASIC Manual, we find that most codes can be stored this way, the exceptions being those in the range 67 to 127,and 195, as these are either unused or are the editing keys ,FUNCTION,DELETE etc. A slight problem arises with the *Statement* keys having codes 230 to 255 (NEW SCROLL etc.) as the ZX81's screen editor does not normally allow these to be input after a REM. Luckily it is easily fooled, just enter the line from right to left, using the ← key to re-position the cursor after each keystroke.

REM at last

In the previous section it was suggested that machine code could be incorporated in a REM statement as the first line of a program. In fact there is no reason why the REM statement should not appear anywhere in the BASIC program except that by putting it as the first line it always occupies the same position in memory, so the machine code always starts at location 16514. If we were to put it anywhere else then we would have to find out exactly where it was in RAM before we could use the machine code routine and any changes to previous lines would probably move it.

However, it may sometimes be a good idea to make the REM line

the *last* line in the BASIC program. As the last line, it is not too difficult to find out where it is in RAM by working backwards from

PEEK 16396 + 256 * PEEK 16397

which gives the starting address of the Display File - which follows immediately after the end of the program area of RAM. The advantage of using the last line is that by POKEing a value of 255 into the first byte of the REM line (the most significant byte of the line number), the line won't be LISTed and the ZX81 won't attempt to RUN it as part of the BASIC program - thus allowing you to use the 'difficult' codes 118 and 126 with impunity, and also protecting it from prying eyes.Although the line is now 'invisible', you will still be able to SAVE and LOAD it along with the rest of the BASIC program.

Quote it

A machine code routine may also be held between quotation marks, as shown below;

100 PRINT " *machine code bytes* "

and the code POKEd or keyed directly as described for a REM line. But take care that the code for a quotation mark (11 , 0B hex) is not included, and of course the line should not be *executed* by the BASIC program. Perhaps the best place to put such a line would be at the end of the program, where it could be made "invisible" , but a REM line is just as good and 2 bytes shorter.

With the Variables

Machine Code may also be stored in the Variable Area of RAM, in space reserved by DIMensioning a suitably sized single dimensioned character or numeric array, e.g;

10 DIM A$(50) or 10 DIM A(10)

which will both reserve space for 50 bytes of machine code.

It is best to make the DIM statement which reserves the space the first line of your program to ensure that the array is placed right at the start of the Variable Area where it can be easily located.

Machine code stored in this area will be SAVEd along with your program, but remember to use GOTO rather than RUN, and not to re-execute the DIM statement if you don't want to lose the stored code.

The main disadvantage of this method of storing machine code is that the Variable Area gets moved around in RAM as the program and the Display File are changed, so you have to be careful in calculating where the machine code is. The main advantage is that there is no restriction on the codes that can be used.

The codes will usually be entered into the array space by POKEing, although there is no reason why direct assignment lines

shouldn't be used - particularly if a string array is being used, as for example;

```
LET A$(2) = CHR$ 222
```

or even;

```
LET A$(2 TO 4) = "A-C"
```

In high RAM

As described in Chapter 26 of the Sinclair ZX81 BASIC Manual, you can reserve space at the top of RAM for a machine code routine by POKEing a new value into the System Variable RAMTOP (locations 16388,16389) and then executing a NEW command. All of the RAM above the new value of RAMTOP is then free for you to use as you wish. But note that the new value of RAMTOP remains until you either POKE a new value or turn the machine off, but - dissapointingly - it is not saved on tape so that every time you want to use a program which takes advantage of this facility you must POKE RAMTOP before LOADing the program.

This area is a good place for machine code because it doesn't interfere with the BASIC program in any way, and once placed there, your code is in a fixed location. The main drawback, however, is that this area of RAM is not SAVEd to tape.

If you have enough memory available, then it is possible to overcome the SAVEing problem by copying the machine code into an array before SAVEing, then copying it back to the top of RAM after loading.

LPRINT Buffer

If you're not using the ZX printer, then the System Variables PRBUFF area (16444 to 16476, hex 403C to 405E) can hold up to 33 bytes of machine code, and the locations 16440, 16507 and 16508 can be used for holding 8 or 16 bit variables.

Unfortunately, this area is cleared whenever a direct command (e.g. RUN or GOTO) is executed.

Hex it

Until now, we have talked in terms of POKEing the machine code bytes directly into RAM, or entering them as their character or keyword equivalents. Both methods make it very difficult to see what you have actually done, and so complicate debugging of the machine code routine.

If you have enough memory, then it is often better to include the hexadecimal form of the machine code in a string or strings within the BASIC program, and have a routine which will translate the hexadecimal into binary bytes and POKE them into the correct memory locations. Because the machine code is now

visible in hexadecimal form, it is easy to check it and to make any necessary changes.

Of course we still have to decide where in RAM the machine code proper is to go, but since the hexadecimal equivalent is now able to be SAVEd along with the rest of the BASIC program, the area above RAMTOP is a good choice. As an example of this technique, we can take the short routine used previously;

```
01 00 00  LD BC, 0000
C9        RET
```

First, enter;

```
POKE 16388,252
POKE 16389,67
```

to reserve 4 bytes at locations 17404,5,6,7 (more bytes will be reserved if you have more than 1K of RAM).

Then enter and RUN the following program;

```
10 LET A=17404
20 LET A$="010000C9"
30 FOR I=1 TO 7 STEP 2
40 POKE A,16*CODE A$(I)+CODE A$(I+1)-476
50 LET A=A+1
60 NEXT I
70 PRINT USR 17404
```

Again, it should set the Z80's BC register pair to zero then print out that value.

All Change 1K

This program is built around a useful Machine Language routine which changes all occurences of one character in the display for another, almost instantaneously.

As listed, it will change any * symbol on the screen to a black square, but this can be altered by adding POKE statements after line 6Ø ;

POKE the code of the character you want changed into 16522,

POKE the code of the new character into location 16535.

```
  1 REM 123456789Ø123456789Ø1234
 1Ø LET A$="2AØC4ØED5B1Ø4Ø3E1723EBA7ED52C819EBBE2ØF5368Ø18F1"
 2Ø LET A=16514
 3Ø FOR B=1 TO LEN A$-1 STEP 2
 4Ø POKE A,16*CODE A$(B)+CODE A$(B+1)-476
 5Ø LET A=A+1
 6Ø NEXT B

1ØØ FOR A=3 TO 18
11Ø PRINT AT A,A;"-*-*-*-*-*-"
12Ø NEXT A
13Ø RAND USR 16514
14Ø EOR A=1 TO 1ØØ
15Ø NEXT A
16Ø CLS
17Ø GOTO 1ØØ
```

Lines 100 to 170 provide a demonstration of the routine's cavabilities, note that RAND USR is the shortest way of using USR if you don't want a result.

Once lines 10 to 60 have been entered and RUN, the machine code is stored in line 1 (which is why it looks funny when listed), and lines 10 to 60 can then be deleted and the variables A,B,A$ CLEARed to make more room for your BASIC program if you wish.

For those interested, the Machine Code routine used is;

```
4Ø82  2A ØC 4Ø            LD HL (4ØØC)     D-EILE
4Ø85  ED 5B 1Ø 4Ø         LD DE (4Ø1Ø)     VARS
4Ø89  3E 17               LD A 17          "*"
4Ø8B  23          LOOP:   INC HL
4Ø8C  EB                  EX DE HL
4Ø8D  A7                  AND A
4Ø8E  ED 52               SBC HL DE
4Ø9Ø  C8                  RET Z            RET IE END
4Ø91  19                  ADD HL DE
4Ø92  EB                  EX HL DE
4Ø93  BE                  CP (HL)          IS IT "*" ?
4Ø94  2Ø F5               JRNZ LOOP
4Ø96  36 8Ø               LD (HL) 8Ø       " "
4Ø98  18 F1               JR LOOP
```

Birds 1K

This is a banal program used to illustrate a useful machine code routine; a horizontal (left to right) scroll.

Each time USR 16514 is executed, everything on the screen is shifted one column to the right, and the first column filled with spaces. The routine won't - however - lengthen a line which is shorter than 32 characters, hence lines 100-130 of the demonstration which fill the first 11 lines of the display with 32 spaces each.

Once the program has been RUN once, lines 10-60 can be deleted, to make room for more useful statements.

```
  1 REM 12345678901234567890
 10 LET A$="0176172A0C4016000237EB9280472571 8F710F3C9"
 20 LET A=16514
 30 FOR B=1 TO LEN A$-1 STEP 2
 40 POKE A,16*CODE A$(B)+CODE A$(B+1)-476
 50 LET A=A+1
 60 NEXT B

100 DIM A$(32)
110 FOR A=1 TO 11
120 PRINT A$
130 NEXT A

200 FOR A=1 TO 100
210 PRINT AT 10*RND,0;">"
220 LET B=USR 16514
230 NEXT A
```

The machine code routine used is, in assembly language form;

```
4082  01 76 17   LD BC 1776
4085  2A 0C 40   LD HL (400C)
4088  16 00      LD D 0
408A  23         INC HL
408B  7E         LD A (HL)
408C  B9         CP C
408D  28 04      JR Z 4094
408F  72         LD (HL) D
4091  57         LD D A
4092  18 F7      JR 408A
4094  10 F3      DJNZ 4088
4096  C9         RET
```

Alien Attack 1K

A fleet of nearly 400 alien space ships is approaching Earth. How many can you blast before the game ends or - worse - you collide with one of them ?

Use keys 6 and 7 to move your ship down or up the screen,and key F to fire. Your score will be shown when the game ends.

The program must be entered in two stages.

First enter;

```
 1 REM 12345678901234567890123456 7
10 LET A$="2A0E404E0600C90176192A1040160002B7EB9280472571 8F71
   0F3C9"
20 LET A=16514
30 FOR B=1 TO LEN A$-1 STEP 2
40 POKE A,16*CODE A$(B)+CODE A$(B+1)-476
50 LET A=A+1
60 NEXT B
```

Check line 10 carefully (there should be 54 characters betwen the quotation marks) , then RUN it.

Next, delete all of the lines except for line 1, which will now look very strange. Then enter;

```
10 LET S=NOT PI
20 LET A=CODE "<"
30 LET B=A
50 LET Z=S

100 FOR D=S TO A*A
110 PRINT AT B,Z;
120 IF USR 16514=A THEN GOTO 300
130 PRINT ">";
140 IF INKEY$="F" THEN GOSUB 500
190 LET B=B-(INKEY$="7" AND B)+(INKEY$="6" AND B<A)

200 PRINT AT RND*A,17;"<"
210 LET C=USR 16521
220 NEXT D

300 PRINT "*";S;P

500 FOR C=Z TO PI
510 IF USR 16514=A THEN LET S=S+1
520 PRINT "-";
530 NEXT C
540 PRINT AT B,Z;">   "
550 RETURN
```

You can then RUN and SAVE the program as normally.

Several tricks have been used to save space and to increase the speed of the game as much as possible. Of particular interest may be line 190, which moves your ship's position (B) according to operation of the keys 6 & 7 but always keeping it within the limits 0 and 19. Also, including the previously unused variable P in line 300 halts the game without needing a separate STOP line.

Two machine code routines are used. The first, starting at 16514, returns the code of the character at the current print position. It is similar to, but faster than;

```
PEEK (PEEK 16398+256*PEEK 16399)
```

In assembly language form, it is;

```
4Ø82  2A ØE 4Ø    LD HL (4ØØE)
4Ø85  4E          LD C (HL)
4Ø86  Ø6 ØØ       LD B Ø
4Ø88  C9          RET
```

The second routine, starting at 16521, is a horizontal (right to left) scroll;

```
4Ø89  Ø1 76 19    LD BC 1976
4Ø8C  2A 1Ø 4Ø    LD HL (4Ø1Ø)
4Ø8F  16 ØØ       LD D Ø
4Ø91  2B          DEC HL
4Ø92  7E          LD A (HL)
4Ø93  B9          CP C
4Ø94  28 Ø4       JR Z 4Ø9C
4Ø96  72          LD (HL) D
4Ø98  57          LD D A
4Ø9A  18 F7       JR 4Ø91
4Ø9C  1Ø F3       DJNZ 4Ø8F
4Ø9E  C9          RET
```

Renumber 1K

By J.Durst.

This program generates a machine code routine which will renumber the lines of a BASIC program, in multiples of 10.

As the length of the program has had to be kept to a minimum to allow it to be used on a 1K ZX81, it does not re-calculate line numbers after GOTO or GOSUB. It does, however, mark them by displaying these numbers in reverse video so they can be recognised easily.

To use the program;

- Enter ;
```
POKE 16388,180
POKE 16389,67
NEW
```
- LOAD the RENUMBER program, and RUN it.
- Enter NEW, to scrap the BASIC version of RENUMBER.
- LOAD the program to be renumbered.
- Enter;
```
FAST
PRINT USR 17732
```
  This should return 0 0/0 when the program has been renumbered.
- Change the line numbers after any GOTOs or GOSUBs.

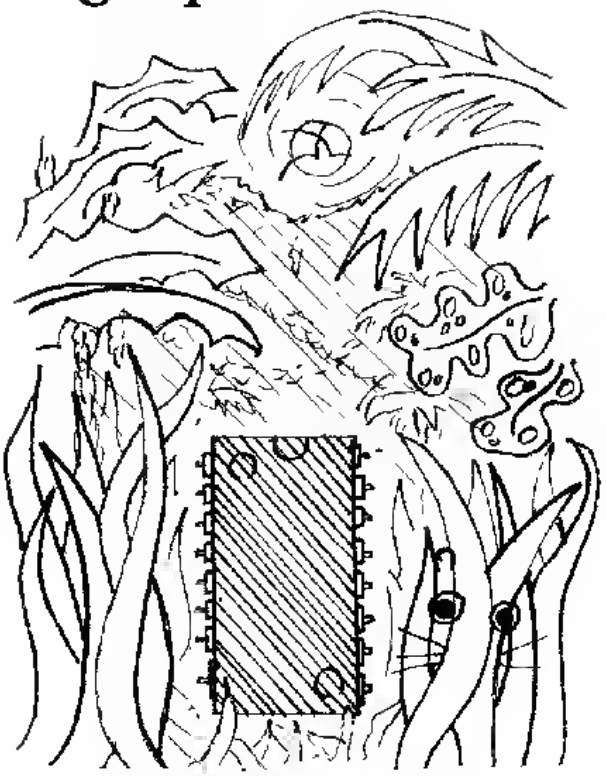
The changed program can now be saved, and another one loaded for re-numbering.

If you have more than 1K of RAM, then for each additional 1K, add 4 to the value 67 POKEd into 16389, add 1024 to the value 17732 in the direct PRINT USR command, and add 1024 to the value 17331 in line 40.

The machine code can be POKEd to give a different start line number or a different interval; POKE the desired values into locations 17333 (Start line) or 17362 (interval). These addresses should be increased by 1024 for each additional 1K of RAM.

```
  10 LET A$="110000 2A0C4 0017F40E
D42E5444D217D40E5180 83E76EDB1280
2180DE5210A0019EBE17223732B18EBE
1C13EECBE280 83CEDA1280 5E018F3230
B3E25BE38EC7ECBFF77233E7EBE20F61
8E0"
  20 FOR J=1 TO LEN A$/2
  30 LET X=J*2
  40 POKE 17331+J,CODE A$(X-1)*16+CODE A$(X)-476
  50 NEXT J
```

Chapter 5



Discovering The ROM

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ROM Routines

The ZX81's 8K ROM contains many routines which are useful to the machine language programmer. The following paragraphs give the starting addresses of the more important ones and a brief description of their function. All addresses and values are given in hexadecimal, and are for the new - 'correct' - ROM , which agrees that SQR 0.125 is 0.5 .

ØØØØ RESET

The ZX81's starting point on power-up. Looks to see how much RAM is fitted - and fills it with zeroes. Sets RAMTOP (4004, 5) to one more than the highest actual RAM address, then goes into the NEW routine. Called by JP 0000 or RST 0.

ØØØ8 REPORT

The ZX81's error report routine and is called by RST 08. The byte following the RST instruction is copied to ERR-NR (4000) and will cause an error halt if it is anything other than FF.

ØØ1Ø PRTCHA

Called by RST 10, prints the character whose code is in the Z80's A register at the current print position. The major portion of the code for the print routines lies from 07F1 and 094A.

ØØ18 GTCHA

Called by RST 18, returns with the A register containing the byte (from your program) pointed to by CH-ADD (4016). Skips spaces - incrementing CH-ADD - and the cursor.

ØØ2Ø GNXCH

Called by RST 20, as GTCHA but skips the character that CH-ADD is currently pointing to.

ØØ3Ø MOREV

Called by RST 30, increases the variable area by the number of bytes given by the BC register pair.

ØØ38 INT

Maskable Interrupt Handler routine, called by a hardware interrupt for each TV line when the ZX81 is generating the display. See 'Display'.

ØØ66 NMI

Non-maskable Interrupt Handler routine, called by a hardware interrupt each TV frame when in the SLOW (compute and display) mode to change between the compute and the display modes. See 'Display'.

Ø1FC NXTBYT

Used by the LOAD & SAVE routines to increment HL to point to the next byte to be LOADed or SAVEd. Jumps to the Display routine at 0207 when HL equals E-LINE.

Ø2Ø7 DISP
The start of the display routines, see 'Display' for full details.

Ø2BB KSCAN
The keyboard scan routine, see 'Display' for full details.

Ø2F4 SAVE
The ZX81's SAVE routine; see 'Recording'.

Ø34Ø LOAD
The ZX81's LOAD routine, see 'Recording' for details.

Ø7F1 OUTCHA
Sends the character whose code is in the Z80's A register to the display if bit 1 of FLAGS (4001) is 0, or to the printer if bit 1 of FLAGS is 1. Uses DISPA (0808) or PNTA (0851).

Ø8Ø8 DISPA
Puts the character whose code is in the A register to the current print position on the TV screen, then updates S-POSN (4039,A) and DF-CC (400E) to point to the next print position.

Ø851 PNTA
Sends the character whose code is in the A register to the printer line buffer PR-BUFF at the position given by PR-CC (4037). If the buffer then holds a complete line, or if the character was NEWLINE (76 hex) the buffer is printed out. PR-CC is then updated.

ØA2A CLS
Performs exactly as the BASIC CLS command.

ØAA1 PHL
Prints the contents of the HL register pair as a decimal number (0 to 9999).

ØAAB PHLS
Prints the contents of the HL register pair as a 4-digit decimal number 0-9999 with any leading spaces being printed as spaces.

ØB6B PSTR
Prints a string. DE should point to the first character in the string, BC should contain the number of characters in the string. The routine will recognise keyword codes (e.g. F8 hex for SAVE) and print them out in their full form.

ØF23 FAST
Change to Fast mode.

ØF2B SLOW
Change to Slow mode.

174C FSUB
Subtracts the 5-byte floating point binary number at (DF) from the 5-byte floating point binary number at (HL).

1755 FADD
Adds the 5-byte floating point binary number at (DE) to the 5-byte floating point binary number at (HL).

17C6 FMLT
Multiplies the 5-byte floating point binary number at (HL) by the 5-byte floating point number at (DE).

1882 FDIV
Divides the 5-byte floating point number at (HL) by the 5-byte floating point binary number at (DE).

ROM Tables

The ZX81 ROM also contains several useful tables, which are briefly described in the following paragraphs. Again, the addresses are given in hexadecimal and are for the new 8K ROM.

ØØ7E - Ø11Ø KEY TABLES

The ZX81 keyboard scanning routines return a 'key number' (1 to 39) if a valid keypress is detected. These Key Tables are used to translate the key number into the appropriate code.

007E to 00A4 is used for the unshifted L mode, e.g. the letters, numbers, '.', space and NEWLINE.

00A5 to 00CB is used for the shifted L mode, e.g. STEP, TO, ')' etc.

00CC to 00F2 is used in the F mode, e.g. for LN, RND etc.

00F3 to 0110 is used in the shifted G mode, for the graphics characters and some inverse symbols.

Ø111 - Ø1FA KEYWORD TABLE

Codes 192 to 255 and 64,65,66 are displayed as more than one character (e.g. SLOW or RETURN). This table holds the 'spelled out' versions of these codes. They are in code order, from codes 192 to 255 then 64,65 and finally 66. The last character of each keyword has bit 7 set to 1.

1EØØ - 1FFF DOT PATTERN TABLE

Holds the dot patterns for each of the codes 0 to 64, eight bytes being used for each code, corresponding to the eight scan lines used to display each character.

LOAD & SAVE

When the ZX81 SAVEs a program to tape, it writes;

- A 5 second silent period.
- The 'name' of the program, exactly as you entered, one byte per character, with the last character inverted (with bit 7 set to 1).
- The contents of RAM from location 16393 (4009 hex) - the System Variable VLRSN - to the end of the Variable Area, which is one less than the address in the System Variable E-LINE.

Each byte is sent to the recorder as eight bits - no start, stop or parity bits are used - with the most significant bit 7 being sent first.

Each bit is recorded as 4 cycles (for a '0') or 9 cycles (for a '1') of approximately 300Hz, followed by a 1.5millisecond pause.

When LOADing, the ZX81 first looks for the silent period, then checks the name - recognising the last character of the name as being the first byte with bit 7 set to 1. It then loads subsequent bytes received from the tape into successive RAM locations starting at 16393 (4009 hex) until it reaches the address which is equal to the just loaded value of the System Variable E-LINE. It then goes to the display routine.

The SAVE Routine

The starting address for the main SAVE routine is 02F6.

It uses the subroutine at 03A8 to put the address of the first byte of the name the program is to be saved under into the DE register pair and set bit 7 of the last byte of the name to 1. The subroutine returns with the C flag set to 1 if no name was given.

The second subroutine called - at 0F46 - returns with the C flag set to zero is the BREAK key is pressed and so halts the SAVE.

The routine at 01FC - which is also used by the LOAD routine - increments HL and terminates the SAVE (or LOAD) by jumping into the Display routine when HL reaches the value of the System Variable E-LINE.

```
Ø2F4  CF ØE          RST 8
Ø2F6  CD A8 Ø3       CALL Ø3A8
Ø2F9  38 F9          JR C Ø2F4
Ø2FB  EEB            EX DE HL
Ø2FC  11 CB 12       LD DE 12CB
Ø2FF  CD 46 ØF       CALL ØF46
Ø3Ø2  3Ø 2E          JR NC Ø332
Ø3Ø4  1Ø FE          DJNZ Ø3Ø2
Ø3Ø6  1B             DEC DE
Ø3Ø7  7A             LD A D
Ø3Ø8  B3             OR E
Ø3Ø9  2Ø F4          JR NZ Ø2FF
Ø3ØB  CD 1E Ø3       CALL Ø31E
Ø3ØE  CB 7E          BIT 7 (HL)
Ø31Ø  23             INC HL
Ø311  28 F8          JR Z Ø3ØB
Ø313  21 Ø9 4Ø       LD HL 4ØØ9
Ø316  CD 1E Ø3       CALL Ø31E
Ø319  CD FC Ø1       CALL Ø1FC
Ø31C  18 F8          JR Ø316

Ø31E  5E             LD E (HL)
Ø31F  37             SCF
Ø32Ø  CB 13          RL E
Ø322  C8             RET Z
Ø323  9F             SBC A A
Ø324  E6 Ø5          AND Ø5
Ø326  C6 Ø4          ADD A Ø4
Ø328  4F             LD C A
Ø329  D3 FF          OUT (FF) A
Ø32B  Ø6 23          LD B 23
Ø32D  1Ø FE          DJNZ Ø32D
Ø32F  CD 46 ØF       CALL ØF46
Ø332  3Ø 72          JR NC Ø3A6
Ø334  Ø6 1E          LD B 1E
Ø336  1Ø FE          DJNZ Ø336
Ø338  ØD             DEC C
Ø339  2Ø EE          JR NZ Ø329
Ø33B  A7             AND A
Ø33C  1Ø FD          DJNZ Ø33B
Ø33E  18 EØ          JR Ø32Ø
```

```
Ø1FC  23             INC HL
Ø1FD  EB             EX HL DE
Ø1FE  2A 14 4Ø       LD HL (4Ø14)
Ø2Ø1  37             SCF
Ø2Ø2  ED 52          SBC HL DE
Ø2Ø4  EB             EX HL DE
Ø2Ø5  DØ             RET NC
Ø2Ø6  E1             POP HL
```

The LOAD Routine

This starts at 0340 and immediately calls the subroutine at 03A8 which points DE to the start of the program name and sets bit 7 of the last byte of the name to '1'. If no name has been given then the C flag is set to '1' and the instructions RLD RRCD set bit 7 of the D register also to 1'1.

The next two instructions; CALL 034C JR 0347 wait for the silent period at the start of each recording. This is done by calling the byte input routine at 034C which will always return (via the RET instruction at 03A1) as long as there are no breaks in the input signal lasting for more than about 5 mS.

This byte input routine is in two parts; the part from 034C to 035D waits for a signal on the tape input port - which causes it to jump to the second part of the routine at 0385 - or for the BREAK key to be pressed - which causes a jump to 03A2 to terminate the LOAD. If no signal is detected on the tape input port within about 5mS, then the program moves on to the routine starting at 035F.

The second part of the byte input routine, from 0385 to 03A1, measures the length of the signal burst coming from the cassette recorder - using the register E as a counter - and so decides if a '1' or a '0' has been received. It then stores the corresponding bit in the C register. When 8 bits have been received so that the C register is holding a complete byte, the routine returns to the calling program, if less than 8 bits have been received it jumps back to 034E to wait for the next bit from the tape.

The remainder of the LOAD routine - 035F to 0384 - first clears the return stack. It then quits, by jumping into the NEW routine at 03E5, if the register D contains zero. This can only happen if there is a loss of signal lasting for more than about 5mS after the ZX81 has found the correct program and started to load it into RAM.
If all is well, it reads the first bytes from the tape, matching them against the given program name. If there is a discrepancy, then the routine jumps back to 0347 to start all over again. If the name matches, then after recognising the last byte of the name as having bit 7 set to 1, the routine moves on to load in the program proper, starting at 0375.

Since the System Variable E-LINE is used as the limit to the LOAD process, its high byte is first incremented to make sure that at least the System Variables are read in - it will later be over-written with the correct value read from the tape.

HL is then pointed at the first RAM location to be loaded (4009) then the data is read from the tape a byte at a time and stored in consecutive RAM locations. The routine at 01FC is used each time to increment the HL pointer and terminate the LOAD when HL is equal to E-LINE.

```
Ø34Ø  CD A8 Ø3     CALL Ø3A8
Ø343  CB 12        RL D
Ø345  CB ØA        RRC D
Ø347  CD 4C Ø3     CALL Ø34C
Ø34A  18 FB        JR Ø347
Ø34C  ØE Ø1        LD C Ø1
Ø34E  Ø6 ØØ        LD B ØØ
Ø35Ø  3E 7F        LD A 7F
Ø352  DB FE        IN A (FE)
Ø354  D3 FF        OUT (FF) A
Ø356  1F           RRA
Ø357  3Ø 49        JR NC Ø3A2
Ø359  17           RLA
Ø35A  17           RLA
Ø35B  38 28        JR C Ø385
Ø35D  1Ø F1        DJNZ Ø35Ø
Ø35F  F1           POP AF
Ø36Ø  BA           CP D
Ø361  D2 E5 Ø3     JP NC Ø3E5
Ø364  62           LD H D
Ø365  6B           LD L E
Ø366  CD 4C Ø3     CALL Ø34C
Ø369  CB 7A        BIT 7 D
Ø36B  79           LD A C
Ø36C  2Ø Ø3        JR NZ Ø371
Ø36E  BE           CP (HL)
Ø36F  2Ø D6        JR NZ Ø347
Ø371  23           INC HL
Ø372  17           RLA
Ø373  3Ø F1        JR NC Ø366
Ø375  FD 34 15     INC (IY+15)
Ø378  21 Ø9 4Ø     LD HL 4ØØ9
Ø37B  5Ø           LD D B
Ø37C  CD 4C Ø3     CALL Ø34C
Ø37F  71           LD (HL) C
Ø38Ø  CD FC Ø1     CALL Ø1FC
Ø383  18 F6        JR Ø37B

Ø385  D5           PUSH DE
Ø386  1E 94        LD E 94
Ø388  Ø6 1A        LD B 1A
Ø38A  1D           DEC E
Ø38B  DB FE        IN A (FE)
Ø38D  17           RLA
Ø38E  CB 7B        BIT 7 E
Ø39Ø  7B           LD A E
Ø391  38 F5        JR C Ø338
Ø393  1Ø F5        DJNZ Ø38A
Ø395  D1           POP DE
Ø396  2Ø Ø4        JR NZ Ø39C
Ø398  FE 56        CP 56
Ø39A  3Ø B2        JR NC Ø34E
Ø39C  3F           CCF
Ø39D  CB 11        RL C
Ø39F  3Ø AD        JR NC Ø34E
Ø3A1  C9           RET
```

Display

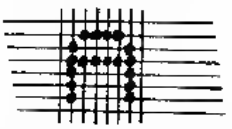
One of the outstanding features of the ZX81 is the way the TV display is generated with the minimum amount of hardware. This as much as anything else allows Sinclair to sell the machine at such a low price. Since many sophisticated ZX81 programs are based on the clever use of the display facilities, it is worth investigating them in some depth.

On the TV

The image on the TV screen is made up from several hundred horizontal lines drawn by a rapidly moving dot. Each line takes 64 micro-seconds to draw, and a complete 'frame' or screen full of lines is drawn every 1/50 th. of a second. (1/60 th. of a second for U.S.A. models). As the dot moves across the screen, it is rapidly turned on and off by the signal from the ZX81 to build up the black and white picture.

To make sure that the picture appears at the right place on the screen, the signal from the ZX81 also includes 'line synchronisation' pulses at the start of each scan line, and 'frame synchronisation' pulses at the end of each complete frame.

Each of the 24 lines of characters which can be displayed on the screen consists of 8 horizontal TV scan lines, and each character position on the screen is made up of 8 possible 'dots' in each of the 8 scan lines;



The dot patterns for each displayable character are stored in the ZX81's ROM, one byte of the ROM being used for each of the 8 TV scan lines for each character. To create the display, the ZX81 has to read the required bytes out of the ROM at the correct times, and use them to generate a sequence of 'black' and 'white' signals to send to the television set.

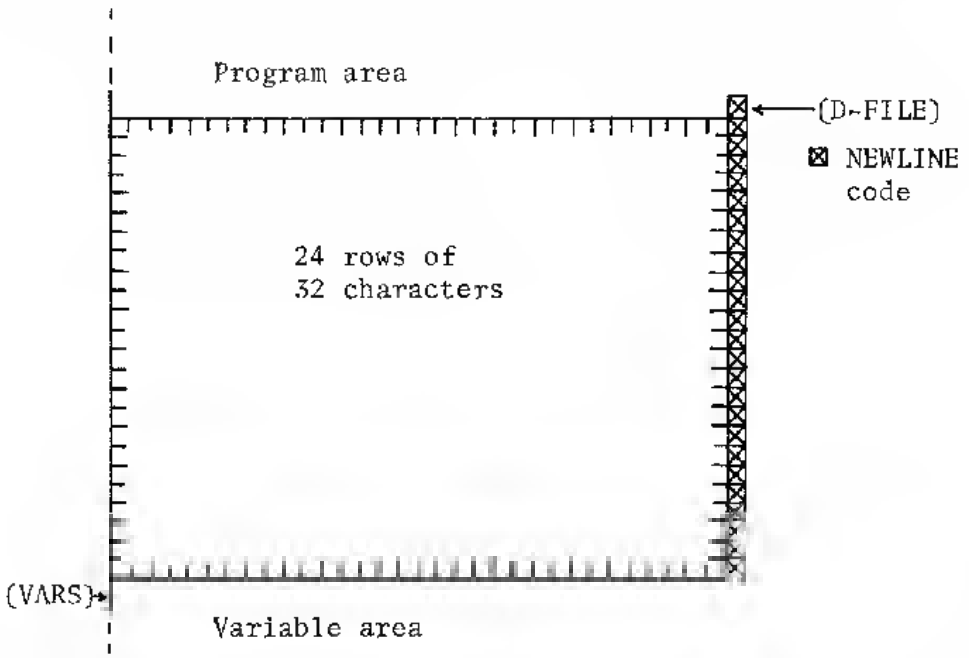
The Display File

This is the area of RAM that holds a 'copy' of whatever is to be displayed on the screen. If your ZX81 has 4K bytes or more of RAM then the Display File will consist of 24 'lines' each containing the 32 characters (including spaces) to be shown, plus a NEWLINE character (CODE 118, hex 76) . A 25th. NEWLINE character is also present at the start of the Display File.

The System Variable D-FILE (16396/7, hex 400C/D) contains the address of the start of the Display File - actually the address of the first (NEWLINE) character, and DF-CC (16398/9, 400F/F) contains the RAM address corresponding to the current print

position, that is, the address of the byte in the Display File which will contain the next character to be printed. Since the Variables Area follows immediately after the Display File, the Syatem Variable VARS (16400/1, 4010/1) contains the address of the RAM byte immediately following the last byte of the Display File.

We can represent the area of RAM taken by the Display File on a ZX81 with 4K or more RAM by a 'screen image' drawing such as;

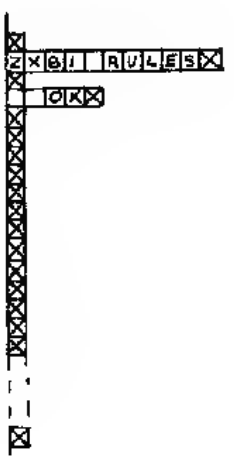


Note however that - even with 4K or more of RAM - SCROLL reduces the display file size by making the new - bottom - line consist of just a single NEWLINE character.

If you have less than 4K RAM, then NEW, LOAD or CLS will 'collapse' the Display File to the minimum of 25 NEWLINE characters, and subsequent PRINT or PLOT statements will only expand it enough to fit in the printed or plotted item. For example;

```
10 CLS
20 PRINT "ZX81 RULES"
30 PRINT AT 2,2;"OK"
```

will result in a Display File looking like;

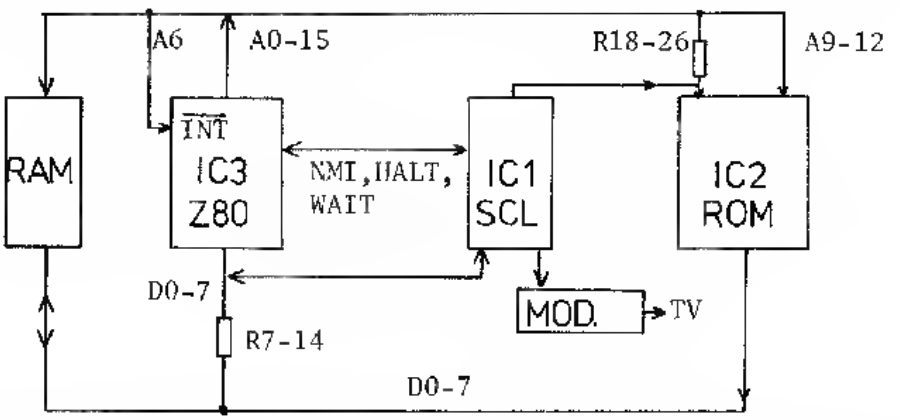


Note that although keywords such as REM or THEN are stored as a single byte in the Program Area of RAM, they are expanded to the correct number of characters in the Display File.

Note also that bits 0 to 5 of each character in the Display File define which character or graphics element is to be displayed, bit 7 is normally 0 but is set to 1 for an inverse (white on black) character or graphics symbol, and bit 6 is 0 except for in the NEWLINE code.

The Hardware

The major circuit elements involved in producing the display are;



When no display is being generated, i.e. when the ZX81 is running your program in FAST mode, the ZX81 functions as a normal micro-computer controlled by the Z80 processor IC3, and the series resistors R7-14 and R18-26 in the data lines and in some address lines have no effect.

However, these series resistors do allow the SCL chip IC1 to 'force' data onto the Z80's data input lines D0-D7 regardless of the current output of the ROM and RAM chips, and similarly IC1 can force the nine least significant address lines A0-A8 to any required state regardless of the address being output by the Z80. Also, IC1 can take data from the data lines D0-D7.

Note also that when the Z80's Maskable Interrupt is enabled by suitable software then any address which has A6=0 put out by the Z80 processor during the end of an instruction cycle will cause an interrupt.

The Z80 processor has the unique ability to generate 'refresh' addresses for use with dynamic RAM chips. After each machine code instruction has been fetched from ROM or RAM, the Z80 puts the contents of its 7-bit internal 'refresh' register R onto the address lines A0-A6 and pulls the RFSH line low while it is decoding the instruction. When it is ready to proceed, the Z80 takes the RFSH line high again and increments the R register. This feature was intended to ease the use of dynamic memories,

but has been used in the ZX81 as the heart of the display mechanism, since certain instructions cause the refresh address to be put out at the time that the Z80 is looking at the Maskable Interrupt input.

The final clues to how the ZX81 generates the display are;

- The SCL chip can detect that the Z80 is fetching an instruction from an address in the top half of memory space, i.e. when A15 is at '1'.
- The NEWLINE code (76 hex) is the Z80's HALT code, and the only code used in the Display File which has bit 6 equal to a '1'.
- When the Z80 is halted, it executes NOP (No Operation) instructions repeatedly while waiting for an interrupt.
- When the contents of the refresh register R are put onto the low 7 address lines, the Z80 also puts out the contents of its 8-bit register I onto the high address lines A8-15.

INT Handler

The maskable interrupt routine from 0038 to 0048 is the heart of the ZX81's display mechanism. It is;

```
ØØ38  0D        INT: DEC C
ØØ39  C2 45 ØØ       JP NZ ØØ45
ØØ3C  E1             POP HL
ØØ3D  Ø5             DEC B
ØØ3E  C8             RET Z
ØØ3F  CB D9          SET 3 C
ØØ41  ED 4F          LD R A
ØØ43  FB             EI
ØØ44  E9             JP (HL)
ØØ45  D1             POP DE
ØØ46  C8             RET Z
ØØ47  18 F8          JR ØØ41
```

If the Maskable Interrupt has been enabled, then this routine is automatically called when the Z80's INT line is pulled low which, as we shall see, happens at the start of each horizontal scan line during the display.

When the routine is called;

- The Z80's C register contains the number of scan lines left for the current row of characters.
- The stack contains the address of the next character in the Display File, with the most significant bit of the address set to '1'. Below this on the stack is the return address to the original calling routine.
- HL contains the address of the first character in the current line in the Display File, again with bit 15 set to '1'.

- The Z80's A register normally contains DD hex.

If , after decrementing C, there are still some scan lines to be generated for the current row of characters, the routine jumps to the POP DE instruction which clears the stack before jumping to LD R A. This instruction, together with the following Enable Interrupt instruction, ensures that 35 instructions later (35 is 100 hex - DD hex) a further interrupt will be caused as bit 6 of the refresh address becomes 0. This sets the basic scan line timing for the display.

Since HL is pointing to the first character of the line to be displayed, the JP (HL) instruction will make the Z80 fetch its next instruction from the Display File ! But, recognising that bit 15 of the address is a '1', the SCL chip will swing into action, storing the character code read from the Display File then forcing a NOP code onto the Z80 data lines D0-D7.

When it has realised that the instruction is a NOP, the Z80 will do nothing except fetch the next byte (from the Display File) as the next instruction to be executed. Again the SCL chip will store the actual code read from the Display File, and give a NOP instruction to the Z80.

This process continues - the Z80 reading consecutive bytes out of the Display File and being fooled into thinking that they are NOPs - until a NEWLINE code is reached. The SCL chip, on seeing this code, stops feeding NOPs to the Z80, and allows it to see the NEWLINE byte. Since the NEWLINE code is 76 hex, the Z80's HALT instruction, the processor will stop doing anything except periodically generating refresh addresses until bit 6 of the refresh address reaches 0, causing an interrupt and so starting the next scan line.

After the last scan line of a particular row of characters, C becomes zero. The interrupt routine then pulls the address of the next byte in the Display File (the first character of the next row) from the stack into HL, and decrements the B register.

If B is now zero - indicating that there are no more rows left to display - then the interrupt routine will return to the calling routine. If B is not yet zero, however, then C is set back to 8 (by the SET 3 C instruction) and the display continues.

As each byte is read from the Display File it is stored in the SCL chip then, during the second (refresh) half of each NOP instruction cycle while the Z80 is putting the contents of its I and R registers onto the address lines, the SCL chip forces the low 9 address lines to the ROM to a pattern consisting of;

- The least 6 significant bits of the character code read from the Display File.
- Three bits defining which of the eight scan lines for each row of characters is being generated.

The high 7 address lines are the high 7 bits of the Z80's 1

register, which is set to 1E hex by the ZX81's power-up routines.

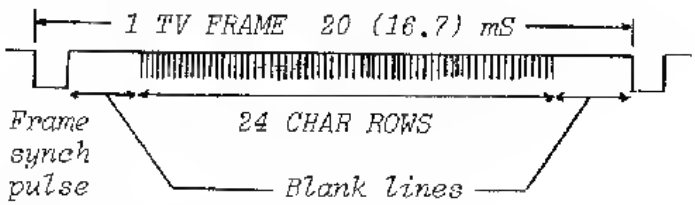
The ROM chip will then output the pattern of eight 'dots' which make up that scan line for that character. These are read into the SCL chip then fed out serially to the UHF modulator and so to your TV.

NMI Handler

As each horizontal TV scan line is completed in 64 micro-seconds, it takes 24 x 8 x 64 micro-seconds - which is just over 12 milli seconde - to output the complete 24 rows of characters displayed in each TV frame. But, to synchronise the TV set properly, each frame must last for 20 milli-seconds (16.7 milli-seconds for the U.S.A. model), so additional - blank - lines are needed to fill in the top and bottom margins of the picture, before and after the frame synchronisation pulse;

VIDEO SIGNAL FOR ONE FRAME.

Line synchronisation pulses omitted for clarity.



When in the SLOW mode, the ZX81 uses the time occupied by these blank lines to carry on with your program. But, to keep track of the time, it is interrupted by the SCL chip every 64 micro-seconds. The Non-Maskable Interrupt is used for this function, and calls the routine starting at 0066 hex;

```
ØØ66  Ø8          NMI: EX AF AF
ØØ67  3C               INC A
ØØ68  FA 6D ØØ         JP M ØØ6D
ØØ6B  28 Ø2            JR Z ØØ6F
ØØ6D  Ø8               EX AF AF
ØØ6E  C9               RET
ØØ6F  Ø8               EX AF AF
ØØ7Ø  F5               PUSH AF
ØØ71  C5               PUSH BC
ØØ72  D5               PUSH DE
ØØ73  E5               PUSH HL
ØØ74  2A ØC 4Ø         LD HL (4ØØC)
ØØ77  CB FC            SET 7 H
ØØ79  76               HALT
ØØ7A  D3 FD            OUT FD A
ØØ7C  DD E9            JP (IX)
```

The Z80 has two pairs of A and F registers, one pair is used for the normal functions of the ZX81, the other pair is reserved for use by the NMI routine.

Within the NMI routine, the A register is used to count the number of blank lines left to display - it is originally set to a negative number, and is incremented each line by the second instruction of the NMI routine. If A has not yet reached zero, the routine simply restores the original AF pair and returns to whatever the ZX81 was doing when it was interrupted.

When A does reach zero, the NMI routine saves the main registers on the stack, then loads HL with the address of the first byte of the display file - setting the most significant bit 15 to 1. The Z80 then halts until the next NMI interrupt is generated by the SCL chip, when it returns to the instruction OUT FD A which turns off the SCL chip's NMI generation circuits. The Z80 then jumps to the return address held in the IX register.

Display Handler

Two subroutines, starting at 0292 and 02B5, are used to set up the ZX81 for the INT and NMI handlers.

```
Ø292  DD E1          PDP IX
Ø294  FD 4E 28       LD C (IY+28)
Ø297  FD CB 3B 7E    BIT 7 (IY+3B)
Ø29B  28 ØC          JR Z Ø2A9
Ø29D  79             LD A C
Ø29E  ED 44          NEG
Ø2AØ  3C             INC A
Ø2A1  Ø8             EX AF AF
Ø2A2  D3 FE          OUT FE A
Ø2A4  E1             POP HL
Ø2A5  D1             POP DE
Ø2A6  C1             POP BC
Ø2A7  F1             POP AF
Ø2A8  C9             RET
Ø2A9  3E FC          LD A FC
Ø2AB  Ø6 Ø1          LD B 1
Ø2AD  CD B5 Ø2       CALL 02B5
Ø2BØ  2B             DEC HL
Ø2B1  E3             EX (SP) HL
Ø2B2  E3             EX (SP) HL
Ø2B3  DD E9          JP (IX)

Ø2B5  ED 4F          LD R A
Ø2B7  3E DD          LD A DD
Ø2B9  FB             EI
Ø2BA  E9             JP (HL)
```

The second routine is called with HL pointing to a byte in the Display File, but with bit 15 set to '1', and with register B containing the number of rows of characters still to be displayed, and C containing the number of scan lines in the first row.

It simply loads A with the value DD - which will subsequently be loaded into the refresh register R of the Z80 at the start of each scan line - then enables the INT interrupt and starts the display with the JP (HL) instruction. The INT handler will then take over, generating the required display as described earlier, and on completion will return to the routine which called 02B5.

The first routine , from 0292 to 02B4, is more subtle and is called to generate the blank lines at the top and bottom of the display.

Having saved the return address to the calling routine in the IX register, and loaded the Z80's C register with the number of blank lines required, it then looks to see if it is in the Fast or the Slow mode.

If the ZX81 is in the Fast mode, the routine jumps to 02A9, where it uses the second routine at 02B5 to generate the blank lines (note that when called the HL register will be pointing to a NEWLINE code in the Display File).

However, if the ZX81 is in the Slow mode, then the instructions at 029D to 02A8 are executed. These load the A register with minus the number of blank lines needed, then enable the SCL chip's NMI generation circuit, then retrieve the Z80's main registers from the stack before returning to running your program - note that this routine starting at 0292 is itself called by the Main Display routine, which has previously stacked the Z80's main registers.

Having enabled the NMI circuits, the SCL chip will then cause an interrupt every 64 micro-seconds which as described earlier will just increment the second A register each time until it reaches zero. The INT handler will then return to the address contained in the IX register, which will be the return address for the 0292 routine, taking it back into the Main Display routine.

The overall effect of calling 0292 is therefore to generate a number of blank TV scan lines, and also to allow your program to proceed while they are being generated if the ZX81 is in the Slow mode. The number of blank lines generated is usually that contained in the System Variable MARGIN (4028).

Set up

This routine first looks at bits 6 & 7 of the System Variable CD-FLAG (403B) and returns if they are both the same.

If they are different, it then sees whether the machine being used is a ZX81 or the older ZX80 which does not have the Slow facility, by trying to enable the SCL chip's NMI gereration circuits with the OUT FE A instruction. It then looks to see if

the A register had been affected. If not, then the computer must be a ZX80 (or a broken ZX81 !) and the routine jumps to 0226 to set bit 6 of CD-FLAG to zero before returning to the calling routine.

If the machine really is a ZX81, bit 7 of CD-FLAGS is set to '1' to indicate the Slow mode, then the main ZX80 registers are saved on the stack before jumping to the Main Display routine at 0229.

```
Ø2Ø7  21 3B 4Ø      LD HL 4Ø3B
Ø2ØA  7E            LD A (HL)
Ø2ØB  17            RLA
Ø2ØC  AE            XOR (HL)
Ø2ØD  17            RLA
Ø2ØE  DØ            RET NC
Ø2ØF  3E 7F         LD A 7F
Ø211  Ø8            EX AF AF
Ø212  Ø6 11         LD B 11
Ø214  D3 FE         OUT FE A
Ø216  1Ø FE         DJNZ Ø216
Ø218  D3 FD         OUT FD A
Ø21A  Ø8            EX AF AF
Ø21B  17            RLA
Ø21C  3Ø Ø8         JR NC Ø226
Ø21E  CB FE         SET 7 (HL)
Ø22Ø  F5            PUSH AF
Ø221  C5            PUSH BC
Ø222  D5            PUSH DE
Ø223  E5            PUSH HL
Ø224  18 Ø3         JR Ø229
Ø226  CB B6         RES 6 (HL)
Ø228  C9            RET
```

Main Display Loop

This routine is executed once for every TV frame displayed. It has several stages;

First, bits 0 to 14 of the System Variable FRAMES (4034/5) are decremented. If bit 15 is a 0 then FRAMES is also being used as the PAUSE counter, and control will be passed back to the calling routine by the RET NC instruction when bits 0 to 14 are all zeroes.

The ZX81 keyboard is then scanned by calling the subroutine at 02BB. This subroutine also starts the TV frame synchronisation pulse. The keyboard scan routine returns a value in the HL register pair corresponding to the key pressed, or FFFF if no key was pressed. This value is saved in the System Variable LAST-K (4025) then the following instructions see whether a valid keypress was detected. If so, and if the machine is in the Fast mode, the RET Z instruction at 0260 returns control to the calling routine. Otherwise, the instructions from 0264 to 0276 update the key debounce status System Variable at 4027.

The OUT FF A instruction at 0227 then ends the TV frame synchronisation pulse in time to start generating the next TV frame. The TV frame is generated in three parts, using the Display Handler routines described previously. First, the blank lines at the top of the screen are generated, then the 24 rows of characters, then finally the blank lines at the bottom of the screen.

Having done this, the Z80 jumps back to the start of the Main Display routine at 0229 to begin the next round, and so it continues until either the end of a programmed PAUSE is reached, or - if in the Fast mode - until a valid keypress is detected. Of course, if you are in the Slow mode, the ZX81 is also executing your program in its 'spare' time during the blank lines at the top and bottom of the screen.

```
Ø229  2A 34 4Ø  ┌──→LD HL (4Ø34)
Ø22C  2B        │   DEC HL
Ø22D  3E 7F     │   LD A 7F
Ø22F  A4        │   AND H
Ø23Ø  B5        │   OR L
Ø231  7C        │   LD A H
Ø232  2Ø Ø3     │ ┌ JR NZ Ø237
Ø234  17        │ │ RLA
Ø235  18 Ø2     │ │ JR Ø239
Ø237  46        │ └→LD B (HL)
Ø238  37        │   SCF
Ø239  67        └──→LD H A
Ø23A  22 34 4Ø      LD (4Ø34) HL
Ø23D  DØ            RET NC
Ø23E  CD BB Ø2      CALL Ø22B
Ø241  ED 4B 25 4Ø   LD BC (4Ø25)
Ø245  22 25 4Ø      LD (4Ø25) HL
Ø248  78            LD A B
Ø249  C6 Ø2         ADD 2
Ø24B  ED 42         SBC HL BC
Ø24D  3A 27 4Ø      LD A (4Ø27)
Ø25Ø  B4            OR H
Ø251  B5            OR L
Ø252  58            LD E B
Ø253  Ø6 ØB         LD B ØB
Ø255  21 3B 4Ø      LD HL 4Ø3B
Ø258  CB 86         RES Ø (HL)
Ø25A  2Ø Ø8       ┌ JR NZ Ø264
Ø25C  CB 7E       │ BIT 7 (HL)
Ø25E  CB C6       │ SET Ø (HL)
Ø26Ø  C8          │ RET Z
Ø261  Ø5          │ DEC B
Ø262  ØØ          │ NOP
Ø263  37          │ SCF
Ø264  21 27 4Ø    └→LD HL 4Ø27
Ø267  3F            CCF
Ø268  CB 1Ø         RL B
Ø26A  1Ø FE         DJNZ  Ø26A
```

```
Ø26C  46          LD B (HL)
Ø26D  7B          LD A E
Ø26E  FE FE       CP FE
Ø27Ø  9F          SBC A A
Ø271  Ø6 1F       LD B 1F
Ø273  B6          OR (HL)
Ø274  AØ          AND B
Ø275  1F          RRA
Ø276  77          LD (HL) A
Ø277  D3 FF       OUT FF A
Ø279  2A ØC 4Ø    LD HL (4ØØC)
Ø27C  CB FC       SET 7 H
Ø27E  CD 92 Ø2    CALL Ø292
Ø281  ED 5F       LD A R
Ø283  Ø1 Ø1 19    LD BC 19Ø1
Ø286  3E F5       LD A F5
Ø288  CD B5 Ø2    CALL Ø2B5
Ø28B  2B          DEC HL
Ø28C  CD 92 Ø2    CALL Ø292
Ø28F  C3 29 Ø2    JP Ø229
```

Keyboard Scanning

This is a fairly straightforward subroutine which is normally called from the Main Display routine, but which can equally well be used by your machine language programs.

It returns a code in the HL register pair corresponding to the key pressed, of FFFF if no key was pressed. It also loads the System Variable MARGIN (4028) with the correct number of blank lines needed at the top and the bottom of the picture; 55 for U.K. machines, 31 for U.S.A. models, by detecting whether pin 22 of IC1 is strapped to 0V or not.

The routine also starts the frame synchronisation pules, so an OUT FF A instruction must appear later to end it.

```
Ø2BB  21 FF FF        LD HL FFFF
Ø2BE  Ø1 FE FE        LD BC FEFE
Ø2C1  ED 78           IN A (C)
Ø2C3  F6 Ø1           OR Ø1
Ø2C5  F6 EØ           OR EØ
Ø2C7  57              LD D A
Ø2C8  2F              CPL
Ø2C9  FE Ø1           CP Ø1
Ø2CB  9F              SBC A A
Ø2CC  BØ              OR B
Ø2CD  A5              AND L
Ø2CE  6F              LD L A
Ø2CF  7C              LD A H
Ø2DØ  A2              AND D
Ø2D1  67              LD H A
Ø2D2  CB ØØ           RLC B
Ø2D4  ED 78           IN A (C)
Ø2D6  38 ED           JR C Ø2C5
Ø2D8  1F              RRA
Ø2D9  CB 14           RL H
Ø2DB  17              RL A
Ø2DC  17              RL A
Ø2DD  17              RL A
Ø2DE  9F              SBC A A
Ø2DF  E6 18           AND 18
Ø2E1  C6 1F           ADD 1F
Ø2E3  32 28 4Ø        LD (4Ø28) A
Ø2E6  C9              RET
```

A second subroutine, at 07BD, translates the 16 bit value into a key number 0-78. It should be called with the 16 bit value in the BC register pair, and returns with the key number in the A register, and HL pointing to the appropriate byte of the key table (007E to 00CB), and the carry flag C set to 1 if only one key had been pressed.

```
Ø7BD  16 ØØ        LD D ØØ
Ø7BF  CB 28        SRA B
Ø7C1  9F           SBC A A
Ø7C2  F6 26        OR 26
Ø7C4  2E Ø5        LD L Ø5
Ø7C6  95           SUB L
Ø7C7  85           ADD A L
Ø7C8  37           SCF
Ø7C9  CB 19        RRC
Ø7CB  38 FA        JR C
Ø7CD  ØC           INC C
Ø7CE  CØ           RET NZ
Ø7CF  48           LD C B
Ø7DØ  2D           DEC L
Ø7D1  2E Ø1        LD L Ø1
Ø7D3  2Ø F2        JR NZ
Ø7D5  21 7D ØØ     LD HL ØØ7D
Ø7D8  5F           LD E A
Ø7D9  19           ADD HL DE
Ø7DA  37           SCF
Ø7DB  C9           RET
```

The hexadecimal values returned in the HL register for the 39 keys are as shown in the table below. 0100 hex should be subtracted from the values given when the SHIFT key is used.

KEY	VALUE	KEY	VALUE	KEY	VALUE
1	FDF7	R	EFFB	J	EFBF
2	FBF7	T	DFFB	K	F7BF
3	F7F7	Y	DFDF	L	FBBF
4	EFF7	U	EFDF	N/L	FDBF
5	DFF7	I	F7DF	Z	FBFE
6	DFEF	O	FBDF	X	F7FE
7	EFEF	P	FDDF	C	EFFE
8	F7EF	A	FDFD	V	DFFE
9	FBEF	S	FBFD	B	DF7F
Ø	FDEF	D	F7FD	N	EF7F
Q	FDBF	F	EFFD	M	F77F
W	FBFB	G	DFFD	.	FB7F
E	F7FB	H	DFBF	space	FD7F

Chapter 6

Hardware

105 Battery Power
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119 16K Byte RAM

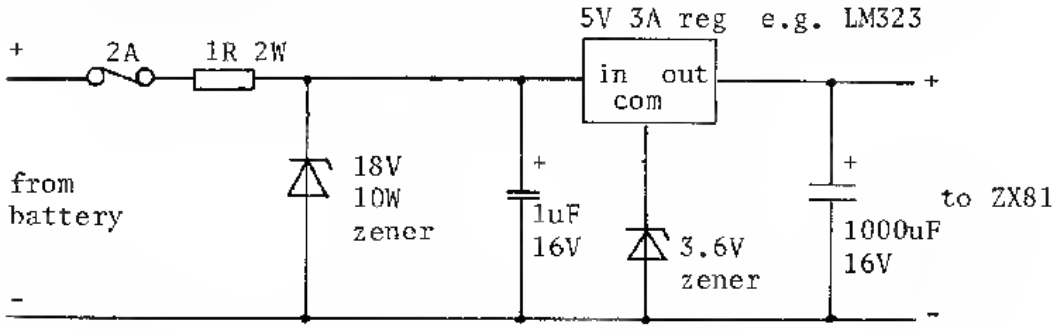
Hardware Hints

This section suggests some ways to improve the ZX81 hardware. Memory and I/O circuits are given at the end of this chapter.

Battery Power

Since portable televisions are available which will run off a 12 volt car battery, it would be nice to be ahle to run a ZX81 from the battery as well, for mohile computing perhaps, or for work during a power cut.

But, a car battery gives nominally 12 volts, which can rise to almost 15 volts when it is being charged heavily, and this is too high for the ZX81. To reduce the voltage to an acceptable level, use the circuit shown below, which will supply sufficient current (at least 1.2A) to drive a ZX81 fitted with a 16K RAM pack and the ZX printer.



The LM323 should be mounted on a heatsink; a piece of 1.5mm (1/16") aluminium 5cm x 8cm (2" x 3") is sufficient. The fuse, 1 ohm resistor and the 18 volt zener protect against voltage spikes coming from the battery lines, and also against reverse polarity connection, the 18V zener will not normally get hot so it does not need a heatsink.

This circuit is also useful if you suffer from frequent mains supply interruptions, which will 'zap' your program easily, as running your system from a car battery - which can either he recharged periodically or trickle charged all the time - should overcome the problem.

Cool it

All electronic equipment works more reliably if it is kept cool. Drilling a row of 1/4" holes along the rear face of the top moulding and some more in the base of the ZX81, near the front, will make a noticeahle difference to the temperature inside the case. But take the case apart first - there are 5 fixing screws in the base, three being hidden by the feet - and carefully remove the printed circuit board first to avoid damaging it.

Getta Betta Jack

Some users have reported that the jack plugs provided on the cassette and power supply leads can cause problems because of poor connections. If this happens then it can be very annoying as even the shortest break in the power supply to the ZX81 will wipe out your program, while erratic cassette connections can ruin a recording or frustrate your attempts to LOAD. Replacing the plugs (they are 3.5mm types), or even soldering the wires directly to the ZX81 PCB, is the only solution.

Support your RAM

The main cause of problems with Sinclair's 16K RAM pack are the connections between it and the ZX81. Even the slightest momentary fault here is liable to corrupt your program or put the ZX81 into its notorious 'white-out' mode.

Unfortunately, the RAM pack is relatively heavy, and the ZX81 is mounted on resilient feet, so that any pressure on the ZX81's keyboard will rock the whole assembly, a procedure which is almost guaranteed to find any poor contacts ! The problem is made worse because the ZX81's contacts are only tinned, not gold plated, and so oxidise very easily.

Techniques used successfully by various ZX81 owners involve thickening the contacts by adding a layer of solder, adding a double-sided gold plated plug extension to the ZX81, cleaning the contacts regularly, fitting a supporting bracket between the ZX81 and the RAM pack to fix them rigidly together, and even soldering the two permanently together ! Whatever you choose to do, try not to remove the RAM pack too frequently as this only wears down the contacts.

Spiky Mains

If your ZX81 keeps crashing or corrupting its program for no apparent reason, suspect large voltage spikes on the mains supply. They are usually caused by electric motors - as in your air conditioning, refrigerator or washing machine - being turned on or off. If you can identify which machine is causeing the spikes then you may be able to plan your computing time along the lines of;

```
IF NOT WASHINGMACHINEON THEN COMPUTE
```

Using another mains outlet may help, or it may make things worse. The ultimate solution is to fit a mains filter in the supply lead to you ZX81 and TV - they are often advertised in most computing and electronics magazines.

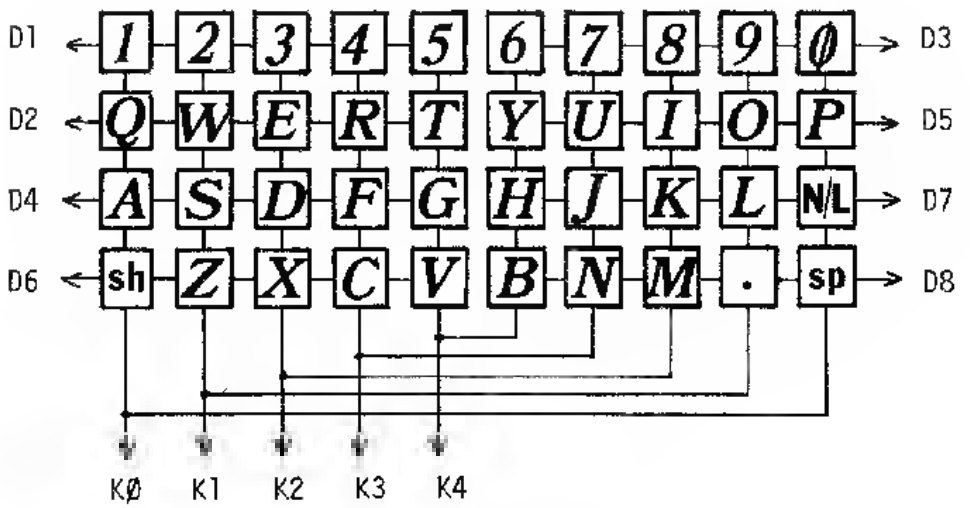
Another Keyboard

The ZX81'a keyboard may be both cheap and aesthetically pleasing, but it is a pain (literally !) to use for any length of time.

Several firms now offer full-size add-on keyboards, but it is

quite easy to make one for yourself from 40 keyswitches (single pole, normally open types), some wire, and some thought about how to mount the finished assembly.

There is no need to disconnect the ZX81's keyboard, the two can be used together, or if you can find a suitable small connector then the new keyboard can be made detachable. In any case, keep the wires as short as is reasonably possible, say 25cm (10") max.



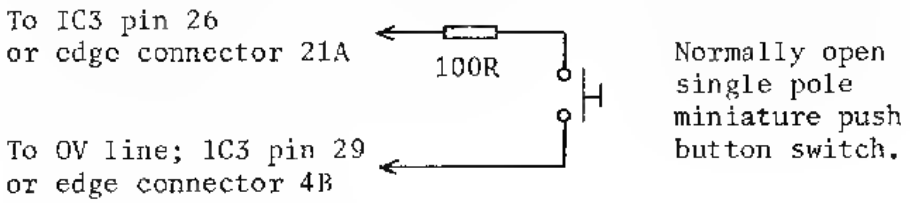
Component side view of corner of ZX81 board showing keyboard connection sockets.

Push to Reset

If you are developing a Machine Language program, or attempting to load a poor quality tape, then you are liable to get your ZX81 into the notorious 'white-out' mode where the TV screen goes blank and none of the ZX81's keys has any effect.

The only way to recover on a standard ZX81 is by switching the power off momentarily. But this can be annoying, and - to the author at least - it seems that repeatedly turning the mains on and off can't be good for the electronic circuits.

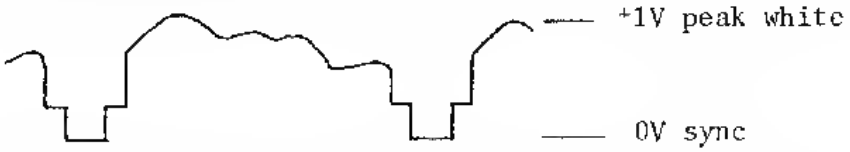
A more sanitary solution is to fit a small push-button switch to the rear of the ZX81's case, and wire it to the processor's RESET input as shown below. Pushing the switch will then put the ZX81 back into a responsive mode just as if you had interrupted the power supply, but in a gentler fashion.You will still lose the program from memory, but that would have happened anyway.



Connecting a Monitor

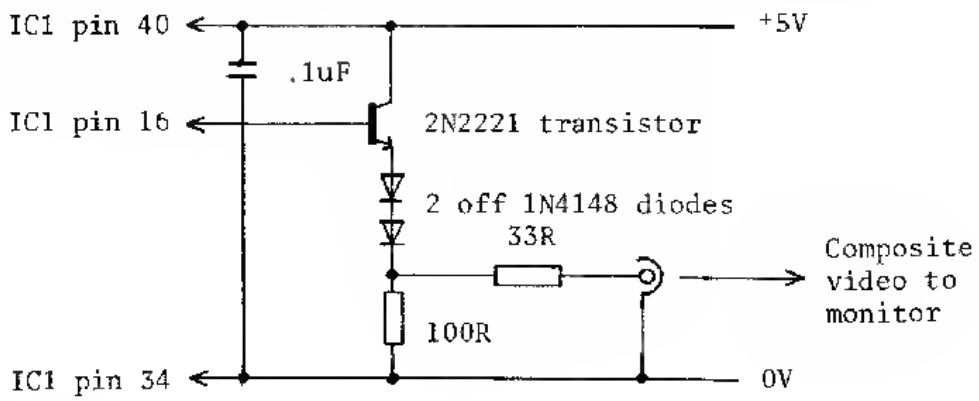
Although the ZX81 gives a good display on most TV sets once the tuning, contrast and brilliance controls have been adjusted, the picture definition is limited by the UHF modulation and demodulation processes, and particularly by the filters in the television receiver.

Anyone lucky enough to possess a monitor can get a much sharper picture by driving it with a composite (video plus sync) signal from the ZX81. Most monitors are designed to work with an input signal looking like;



and generally the impedance at the monitor's video input socket will be 75 ohms for feeding via co-axial cable.

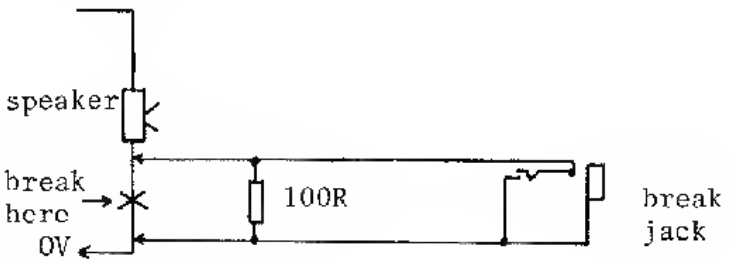
The ZX81 can be modified to give a suitable composite video output by adding the circuit shown below. It picks the video signal from the SCL chip output, and buffers it so that the ZX81 UHF and TAPE outputs are not affected by the loading of the monitor input impedance. With care the components will fit between the ZX81's EAR socket and the UHF modulator box, and a phono socket can be mounted on the rear of the case.



From the Speaker

By connecting a suitable resistor and a jack socket in series with the loudspeaker of your cassette recorder, as shown below, you will be able to hear the signal while LOADing. This is a very useful facility when trying to LOAD from a difficult tape, as at least you can tell when the ZX81 *should* have finished LOADing.

Experiment with the value of the resistor to get the best level of sound from the speaker - or you could fit a 1K potentiometer connected as a variable resistor to allow you to vary the sound level as required.



Recording

There is nothing more aggravating that finding that the only tape you had made of an important program won't load. So it is well worth while investing a few hours in finding the most reliable settings for your cassette recorder controls and the best brand of tape. (It is also worth getting into the habit of saveing more than one copy of each program !)

If you are still unable to SAVE and LOAD programs successfully despite experimenting with your recorder's level and tone controls, and even after trying several brands of tape, then;

- Try removing the EAR connector when SAVEing, and removing the MIC connector when LOADing. Some cassette recorders do not like simultaneous connections .
- If you have been running your recorder from mains, try if possible to run it from batteries to reduce any possible mains hum.
- If you are running your recorder from batteries then make sure that they are fresh. It is also worth noting that doing a fast rewind can temporarily deplete the batteries so in that case give them a minute or two to recover before starting to LOAD or SAVE.

- Make sure that the tape head is well past the end of the tape leader film - and allow the recorder a few seconds to pick up speed - before pressing NEWLINE when SAVEing.
- Make sure that the cassette recorder head is clean.
- The recorder should be at least one metre away from your television, monitor, or any other potential source of radiated interference. CB sets can sometimes be a nuisance, a Breaker's Break-in can get SAVEd along with your program and will totally confuse the ZX81 when you try to LOAD.
- Listen to the signal recorded onto the tape. The silent period should be *silent*, without any stray whistles, pops, crackles or frying noises. The high pitched buzz following should sound crisp and again should be free of any interfering noises. While you are doing this make sure that the plug connections are firm and that they and the recorder level and tone controls aren't responsible for adding any unwanted background to the signal.
- Some cheap cassette recorders use a permanent magnet to bias the record head and also for erasing the tape. With these, repeated recording on the same tape will build up a background hiss which the ZX81 can find disconcerting. Invest in a new tape, or have it wiped clean by a recorder with AC erase or on a bulk cassette eraser.

Overall, the ZX81 likes a signal that is free of wow and flutter or any extraneous noise, from a cassette player that is running at somewhere near the correct speed - if you can LOAD your own recordings but have difficulty with other peoples', then suspect the record/playback head or the tape speed on your recorder.

More esoteric causes of failure are poor azimuth (which means -roughly- that the record/playback head is in the wrong position relative to the tape) or DC magnetisation of the head, but these are unlikely. A few cassette players may not be able to give enough voltage to drive the ZX81 - which likes at least 0.5 volts r.m.s - in this case you could try using the speaker output as described previously.

Memory Map

The ZX81's RAM and ROM address decoding uses the address lines AØ to A15 as follows;

ZX81 Address Line;	A15	A14	A13	A12	A11	A1Ø	A9	A8	-----	AØ
ROM		Ø		A	A	A	A	A	------	A
RAM 1K		1					A	A	-----	A
RAM 16K		1	A	A	A	A	A	A	------	A

Where the 'A's are the address lines used internally by the ROM or RAM chips.

A15 is brought to a '1' when the ZX81 is fetching a character to be displayed from RAM, at other times it is 'Ø'.

Because not all of the address lines are used, 'echoes' of the ROM and RAM appear throughout the 64K address space. The resulting memory map is;

FFFF	65535	Echoes of lower 32K, used in display mode.
8ØØØ	32768	
7FFF	32767	16K RAM space (if only 1K RAM fitted, it will echo throughout this space)
4ØØØ	16384	
3FFF	16383	Echo of 8K ROM
2ØØØ	8192	
1FFF	8191	8K ZX81 BASIC ROM
ØØØØ	Ø	

There seems to be a lot of address space wasted on 'echoes', even when the 16K RAM pack is fitted, so it is interesting to speculate on how much memory could be fitted to a ZX81 without resorting to complicated 'bank-switching' schemes.

Starting with the basic 1K RAM ZX81, we can disable the internal RAM (to make room for bigger things) by simply connecting RAM.CS (the edge connector pin 2A) to +5V.

To remove the echoes of the 8K ROM, we have to disable it when either A15 or A13 are at '1'.

Having cleared the decks, let us see where we can put RAM, other than the 'traditional' 16K space from 4ØØØ to 7FFF. The 8K area 2ØØØ-3FFF seems a good choice, except that the ZX81 won't allow the BASIC program, variables or display file to be put here. It would be suitable, however, as a temporary storage area for data or machine code.

Above 8ØØØ however, we run into the ZX81's display generation mechanism. Basically this involves a machine code routine that;

- Puts the address of the start of the current line to be displayed into the Z80's HL register pair.
- Sets the most significant bit of the HL register pair to '1'
- Does a 'Jump' to the address in HL.

Special hardware then recognises that the Z80 is fetching a machine code instruction from an address with A15 set to '1', and does two things;

- It collects the byte read out from RAM (which will be from the display file) as being the next character to be sent to the TV display.
- It feeds a NOP (no operation) instruction to the Z80.

On seeing the NOP instruction, the Z80 increments the address to fetch the next instruction.

This goes on - the Z80 steadily fetching the characters to be displayed from RAM but seeing NOP codes instead - until a NEW LINE character is fetched.

What all this means in terms of adding memory is that the Z80 expects to see the display file area of RAM appear in two places; its 'normal' position and also some 32768 (8ØØØ hex) bytes higher when generating the display.

Luckily the echo of the display file is always accessed by a Z80 instruction fetch cycle, which is signalled by the M1 line from the Z80 going low. If we can be sure that the 'extra' RAM won't be accessed by a Z80 instruction fetch cycle, then we can use the M1 line to switch between the new RAM and the echo of the display file in lower RAM. We can be sure of this by keeping the new area of RAM free of machine code routines.

Summarising, we could put 56K of RAM onto a ZX81;

- 8K bytes from 2ØØØ to 3FFF, as a 'scratch pad' area for data or machine code. It won't be SAVEd.
- 16K bytes from 4ØØØ to 7FFF, with no restrictions on use.
- 32K bytes from 8ØØØ to FFFF, which can be used as an extension to the Variables area, but must not hold machine code. This area can be SAVEd in the normal way.

One word of caution however, the ZX81 would take about 20 minutes to SAVE or LOAD 48K bytes, and the chances of an error occuring during this length of time must be quite high !

Pseudo-ROM

The dot patterns for the displayable characters are held in a table in ROM, in locations 1E00 to 1FFF hex. The patterns are stored in order of the character CODE, 8 bytes being used for each character, corresponding to the 8 TV scan lines used to build up each character on the TV screen. The ROM table holds the dot patterns for 64 characters, the other 64 are the inverse (white on black) versions and are produced by the SCL chip inverting the video signal.

Looking at, for example, the character 'Ø', this has the CODE 28 (1C hex) and is generated by the 8 ROM bytes starting at 1EE0 hex (1E00 + 1C x 8). The hexadecimal and binary values of these 8 bytes are shown alongside and the pattern can be seen in the binary version.

Addr.	Hex.	Binary
1EEØ	ØØ	ØØØØØØØØ
1EE1	3C	ØØ1111ØØ
1EE2	46	Ø1ØØØ11Ø
1EE3	4A	Ø1ØØ1Ø1Ø
1EE4	52	Ø1Ø1ØØ1Ø
1EE5	62	Ø11ØØØ1Ø
1EE6	3C	ØØ1111ØØ
1EE7	ØØ	ØØØØØØØØ

When the ZX81 is producing the display, it presents 13 bit addresses to the ROM to select the wanted 8 bit patterns. The low 9 address lines, which specify which character is being displayed and which of the 8 horizontal scan lines is currently being generated, come from the SCL chip. The high 4 address lines come from the Z80 processor and are actually bits 1 to 4 of the Z80's I register, which is set to 1E hex by NEW.

Because the starting address of the table is determined by the contents of the Z80's I register, we can alter it. As a demonstration, the following program displays 64 characters then loads the I register with Ø, making the ZX81 use the beginning of the ROM as a dot pattern table. Ten seconds later, the display will be returned to normal by restoring the correct value to the I register.

```
  1 REM 12345
 1Ø POKE 16514,62
 2Ø POKE 16515,Ø
 3Ø POKE 16516,237
 4Ø POKE 16517,71
 5Ø POKE 16518,2Ø1
1ØØ FOR A=Ø TO 63
11Ø PRINT CHR$ A;
12Ø NEXT A
13Ø RAND USR 16514
14Ø PAUSE 5ØØ
15Ø POKE 16515,3Ø
16Ø RAND USR 16514
```

The machine code routine used is;

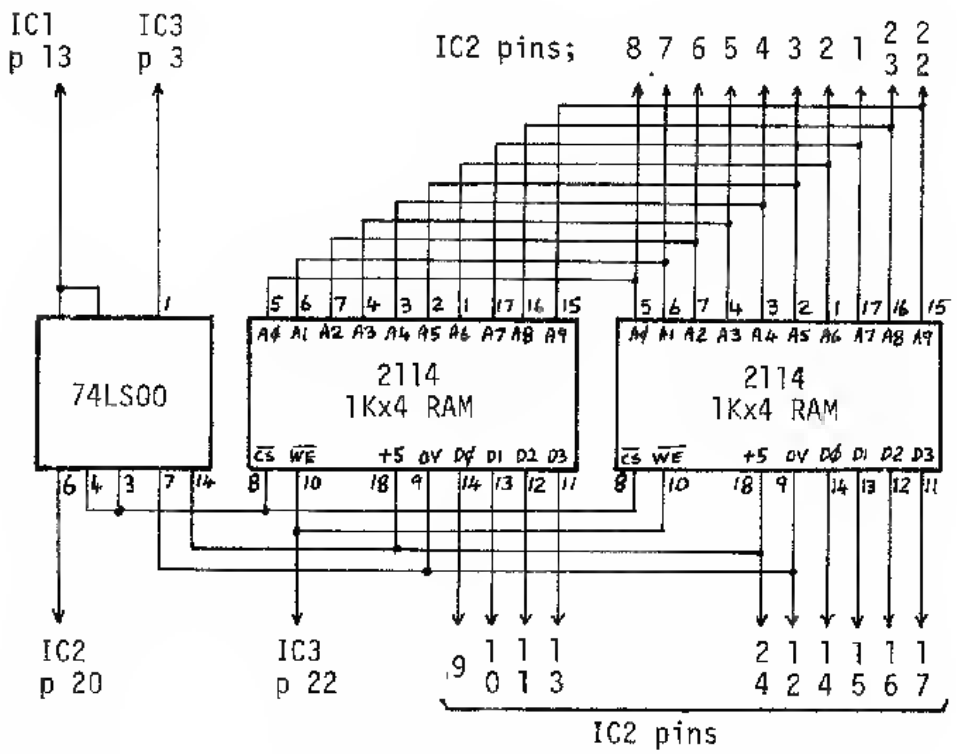
```
3E ØØ     LDA Ø
ED 47     LD I A
C9        RET
```

As the beginning of the ZX81's ROM wasn't intended to be used as a dot pattern table, it gives a meaningless display ! But, if we were to add some RAM to the ZX81, in such a way that the

display generation circuits could use it, then we could POKE any dot patterns we wanted into this 'Pseudo ROM', and so create our own character set. This could include shapes for games programs, mathematical or engineering symbols, or elements for high resolution drawings.

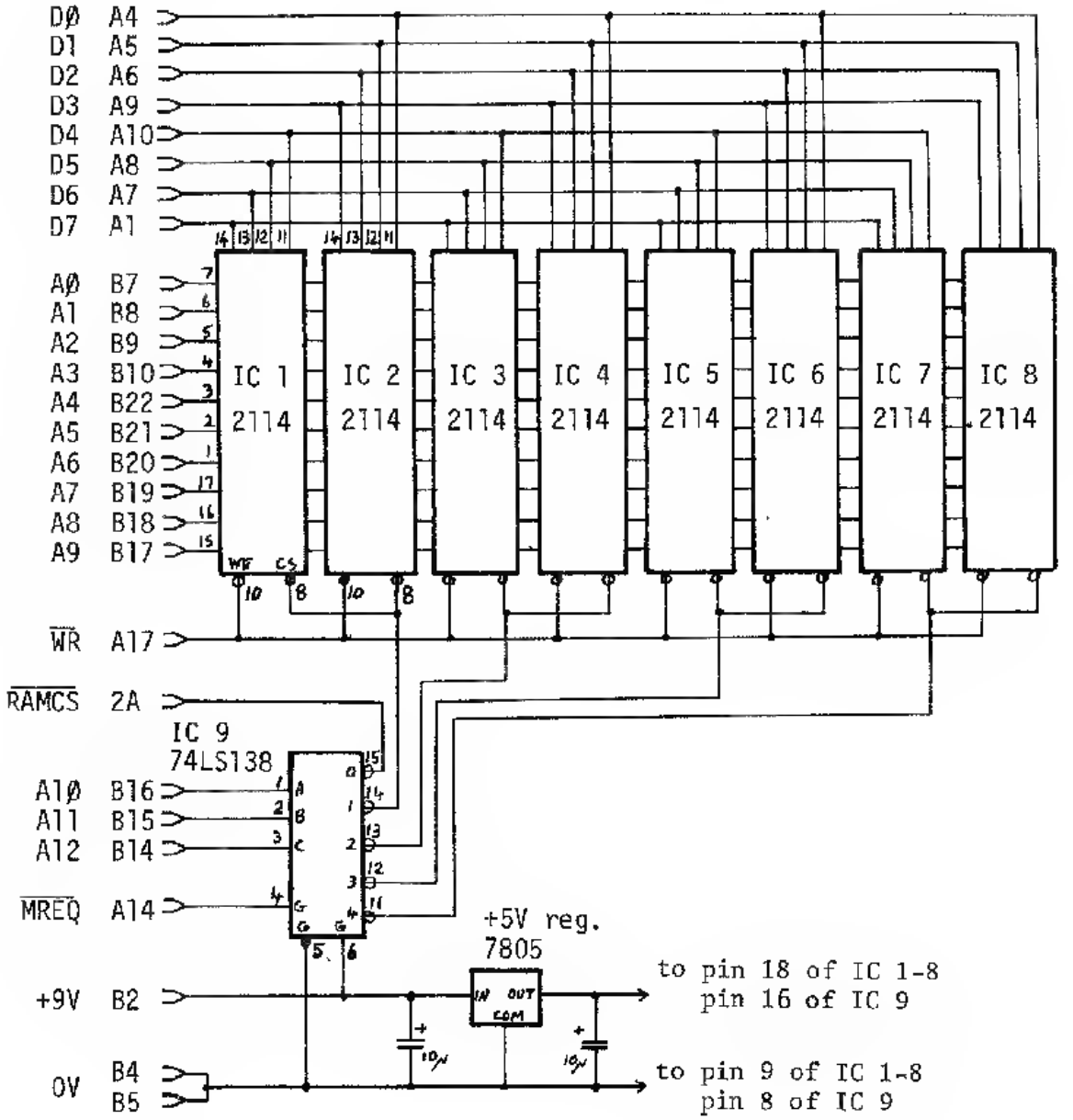
The circuit given below shows how 1K of RAM can be added in this way. Because all of the wanted signals are not present on the ZX81's rear connector, the 'Pseudo ROM' is best fitted inside the ZX81's case, with the connections wired directly as shown. The extra current taken from the +5V supply will make the ZX81's regulator run slightly hotter, but you have drilled cooling holes in the case, haven't you ?

It occupies addresses 2000-23FF hex (8192-9215 decimal). This is enough for 2 sets of 64 characters, or you could load just one set of characters and have 512 bytes left to hold machine code or other data. The routine given on the previous page can be used to force the ZX81 to use the dot patterns held in the Pseudo ROM by changing the value POKEd by line 20 to 32 to select the lower ½K of the Pseudo ROM, or 34 to select the upper half. Data (including dot patterns) stored in the Pseudo ROM won't be SAVEd, but neither is it affected by NEW or LOAD, so you can run one program to fill the Pseudo ROM with appropriate data, then LOAD another program to use it.



Note; R28 (680 ohm) to be removed from ZX81 board.

1-4K RAM Extension



This circuit is for a board which will plug onto the ZX81's rear connector, adding up to 4K of RAM to the existing 1K.

For 1K extension, fit ICs 1,2 and 9.
For 2K fit also ICs 3 and 4.
For 3K fit also ICs 3,4,5 and 6.
For 4K fit all ICs.

The 7805 5V regulator should be mounted on a 5cm. (2") square heatsink.

24 Line I/O

The circuit given on the following page is for an add-on board that will plug into the ZX81's rear connector and provide 24 bi-directional Input/Output lines. These could be used to control music synthesisers, model train layouts, or whatever you wish.

Because the ZX81 has 1K resistors in series with the data lines DØ-D7, which severely limit the possible DC and AC loading of these lines, a specialised MOS I/O chip has been used. This imposes virtually no DC load on the data lines and only a slight AC load. It is also an attractive choice because it is a very versatile IC, which can provide many types of I/O function.

As well as the 64K byte RAM/ROM address space, the Z80 processor can also use a separate, smaller, address space for I/O ports. However, this I/O address space cannot be accessed directly from BASIC using PEEK or POKE, but needs a machine language routine. To simplify matters, the I/O port described here has been put into the Z80's normal RAM/ROM address space, at locations C000 to C003 hex, where it will not interfere with the ZX81's 8K ROM or up to 16K RAM.

If your ZX81 has only the basic 1K of RAM, then pin 8 of IC3 on the I/O board should be connected to pin A2 of the ZX81 rear connector; the RAMCS line. If, however, you have an external RAM pack, then you should;

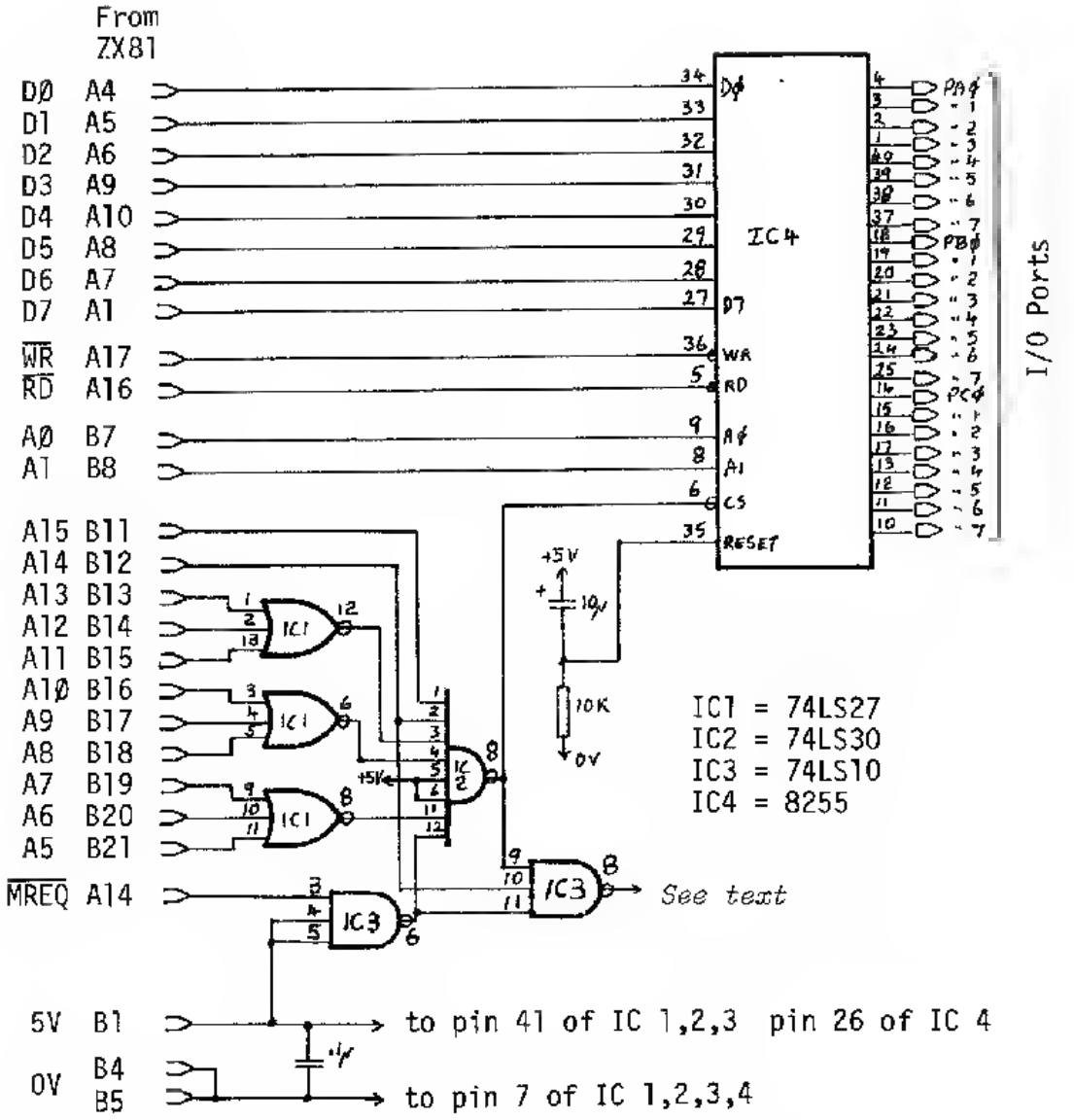
- Add a 23+23 way double sided plug to the I/O board so that the RAM pack can be plugged on. All pins *except for pin A14* on this plug should be wired to the corresponding pins of the I/O board's 23+23 way socket.
- Connect pin 8 of IC3 on the I/O board to pin A14 of the plug which will mate with the RAM pack.

If you have a printer then this can be connected between the ZX81 and the I/O board.

The following paragraphs summarise the main features of the 8255 Programmable Peripheral Interface chip, giving enough information for most purposes. For more complex applications, you would need to refer to the 8255 data sheets.

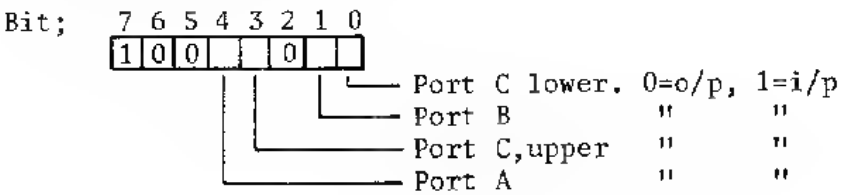
The 8255 has three 8-bit I/O ports (A,B and C), which can be written to (when they are in the output mode) or read from as sigle byte registers. It also has an internal 8-bit control register which can only be written to. In the circuit shown, the addresses of the four registers are;

	Hex	Decimal
Port A	C000	49152
Port B	C001	49153
Port C	C002	49154
Control	C003	49155



It may be set up - by writing special codes to the control register - to one of three modes. Mode 0 is the simplest, and suitable for most applications.

In mode 0, ports A and B may each be set up as 8 input lines or as 8 output lines. Port C is divided into upper and lower 4-bit halves, each of which may be set up to act as input or output. To set up the 8255, we need to write into the control register a byte constructed as;



Thus to set Port A for output, B for input, and both parts of Port C for input, we need to write an 8-bit pattern 10001011 to the Control register.

Remembering that;

If bit 7 = 1	this	corresponds	to	decimal	128
" " 6 = 1	"	"	"	"	64
" " 5 = 1	"	"	"	"	32
" " 4 = 1	"	"	"	"	16
" " 3 = 1	"	"	"	"	8
" " 2 = 1	"	"	"	"	4
" " 1 = 1	"	"	"	"	2
" " 0 = 1	"	"	"	"	1

then we can set up the 8255 by the BASIC statement;

POKE 49155, 139 *(139 = 128+8+2+1)*

Having set up the 8255, we can now send a pattern to the output port A by;

POKE 49152,X *(X is the pattern; 0-255)*

The pattern on the 8 input lines connected to the B port can be read by;

LET A=PEEK 49153

and similarly, all 8 port C inputs can be read by;

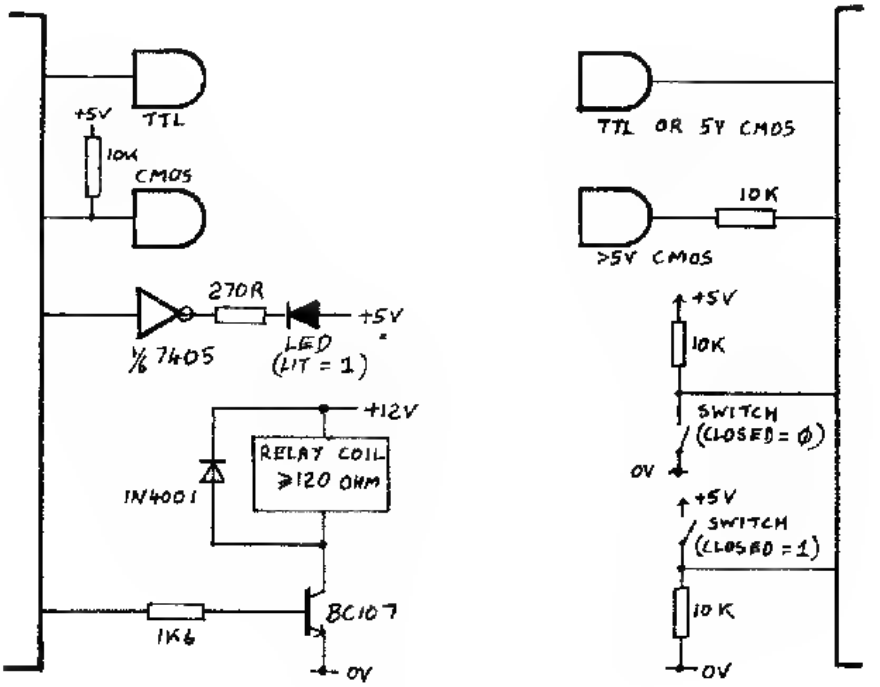
LET A=PEEK 49154

If either half of the C port has been set up for output, then any of the lines may be set or reset individually at any time by POKEing one of the following values to the Control register;

Value POKEd	Effect
0	PC0 reset to 0
1	PC0 set to 1
2	PC1 reset to 0
3	PC1 set to 1
4	PC2 reset to 0
5	PC2 set to 1
6	PC3 reset to 0
7	PC3 set to 1
8	PC4 reset to 0
9	PC4 set to 1
10	PC5 reset to 0
11	PC5 set to 1
12	PC6 reset to 0
13	PC6 set to 1
14	PC7 reset to 0
15	PC7 set to 0

When set up as output lines, the 8255 outputs can each drive one standard TTL load. When acting as inputs, they present a high

impedance to the driving source, and accept an input voltage of less than 0.8V as a '0', or a voltage between 2.0 and 5.0V as a '1'. Some useful interface circuits are shown below;

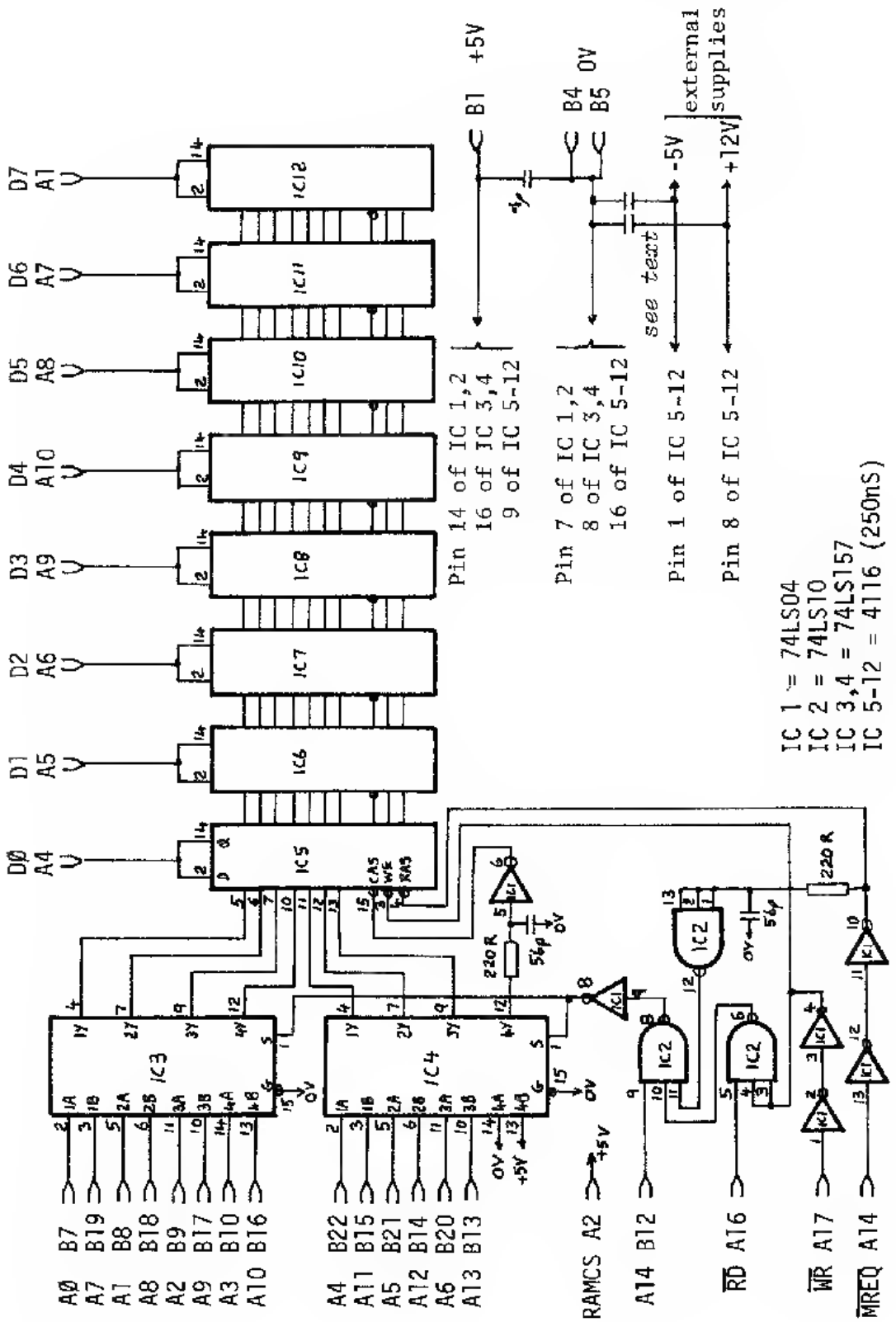


16K Byte RAM

The circuit on page 120 is for a 16K byte RAM extension board to plug onto the ZX81's rear connector. Connecting the board disables the ZX81's internal 1K RAM, but it is compatible with the Pseudo ROM and 24 line I/O circuits given earlier.

4116 dynamic RAM ICs have been used for low cost, but they do require additional - externally generated - supplies of +12V at 150mA and -5V at 5mA.

Because of the relatively poor noise immunity of the ZX81's data bus lines, and also because of the large current spikes drawn by the RAM chips, the constructor should make the board as small as is reasonably possible, with short connections. The 0V, -5V and 12V supplies should be fed in a 'grid' fashion to the 4116 chips, and a 0.1uF capacitor connected between the 0V and 12V lines, and another between the 0V and -5V lines, at alternate 4116's. Also, a 10uF solid tantalum bead capacitor should be connected between 0V and 12V, and another between 0V and -5V.

If all is well, then when the extension board is connected to the ZX81 and power applied the familiar K cursor should appear on

the screen and all previous programs should run without difficulty. The RAMTEST program given elsewhere in this book can then be run to check the new memory thoroughly.